American Magnetics, Inc.

P.O. Box 2509, 112 Flint Road, Oak Ridge, TN 37831-2509
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AMI MODEL 4Q05100PS
4-QUADRANT POWER SUPPLY
INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

I. INTRODUCTION

The AMI Model 4Q05100PS is designed to provide a compact, 4-quadrant capability for AMI power supply systems. The Model 4Q05100PS is designed to operate with the AMI Model 420 Power Supply Programmer.

II. SPECIFICATIONS

AC Input Voltage:	100-120 VAC or 200-240 VAC ±10%[1]
AC Input Frequency:	47 to 63 Hz
DC Output Current/Compliance:	±100 A @ ±4.0 V, ±80 A @ ±4.7 V, ±60 A @ ±5.0 V
Power-Absorbing Mode[2] Rating:	325 VA max. @ 25°C, linearly derated to 295 VA max. @ 40°C
Output Overvoltage Protection:	±6 VDC (nominal)
Ambient Temperature Rating	0 to 40°C
PROGRAM IN Control Signal:	–10 to +10 VDC[3]
Output Voltage Noise:	0.6 mV RMS into 20 MHz BW (typical) 10 mV p-p into 20 MHz BW (typical) 75 mV p-p into 20 MHz BW (maximum)

[1] Input voltage range is selectable via an internal switch.

[2] The supply is in absorbing mode when the polarity of the output voltage is opposite the polarity of the current flow.

[3] Gain of 0.5 is applied to the voltage output of the unit.

Rev. 1, November 1999

III. INSTALLATION

The AMI Model 4Q05100PS is designed to operate in an AMI power supply system consisting of a power supply programmer and a superconducting magnet. The following paragraphs document the procedures and interconnects necessary to use the Model 4Q05100PS.

> ***WARNING:*** *Before energizing the instrument, the earth ground of the power receptacle must be verified to be at earth potential and able to carry the rated current of the power circuit. Using extension cords should be avoided, however, if one must be used, ensure the ground conductor is intact and capable of carrying the rated current.*

> ***WARNING:*** *In the event that the ground path of the instrument becomes less than sufficient to carry the rated current of the power circuit, the instrument should be disconnected from power, labeled as unsafe, and removed from place of operation.*

> ***WARNING:*** *Do not operate this instrument in the presence of flammable gases. Doing so could result in a life-threatening explosion.*

> ***WARNING:*** *Do not modify this instrument in any way. If component replacement is required, return the instrument to AMI facilities as described in the Troubleshooting section of this manual.*

> ***WARNING:*** *If this instrument is used in a manner not specified in this manual, the protection provided by the design, manufacture and documentation of the instrument may be impaired.*

A. Carefully remove the Model 4Q05100PS from the shipping container and remove all packaging material.

> *NOTE: If there is any shipping damage, save all packaging material and contact the shipping representative to a file a damage claim. Do not return the instrument to AMI unless prior authorization has been received.*

B. If the Model 4Q05100PS is to be mounted in a rack:

1. Install horizontal support rails in the rack to support the weight of the Model 4Q05100PS. Securing the front panel alone is not adequate support for the weight of the unit.

2. Install the Model 4Q05100PS in the 19" wide instrument rack by securing the front panel to the rail in each of the four corners with mounting hardware supplied by the cabinet manufacturer.

C. Ensure the front panel power switch is in the OFF (**O**) position. Verify that the instrument is configured for the proper operating voltage by referring to the label adjacent to the power entry module on the rear panel of the instrument. If the operating voltage is correct, plug the line cord into the appropriate power receptacle.

> ***WARNING:*** *The Model 4Q05100PS operates on 50-60 Hz power and may be configured for 100-120 or 200-240 VAC. The power requirement for each instrument is marked on the rear panel of the instrument adjacent to the power entry module. Be sure your instrument is configured for your power source prior to plugging in the line cord. Do not fail to connect the input ground terminal securely to an external earth ground.*

If the instrument operating voltage needs to be changed, the unit must be returned to AMI.

D. Install the power supply in the superconducting magnet system. The figure on the following page illustrates the interconnects for an AMI Model 4Q05100PS power supply.

Connect the cabling in the following manner:

1. Connect the positive (+) power supply terminal (1) to the positive vapor-cooled current lead (2) using 1/4-20 or similar hardware.

> ***NOTE:*** *The use of locking hardware is recommended for all high current connections.*

2. Connect the negative vapor-cooled current lead (3) to the positive (+) shunt terminal (4) on the back of the Model 420.

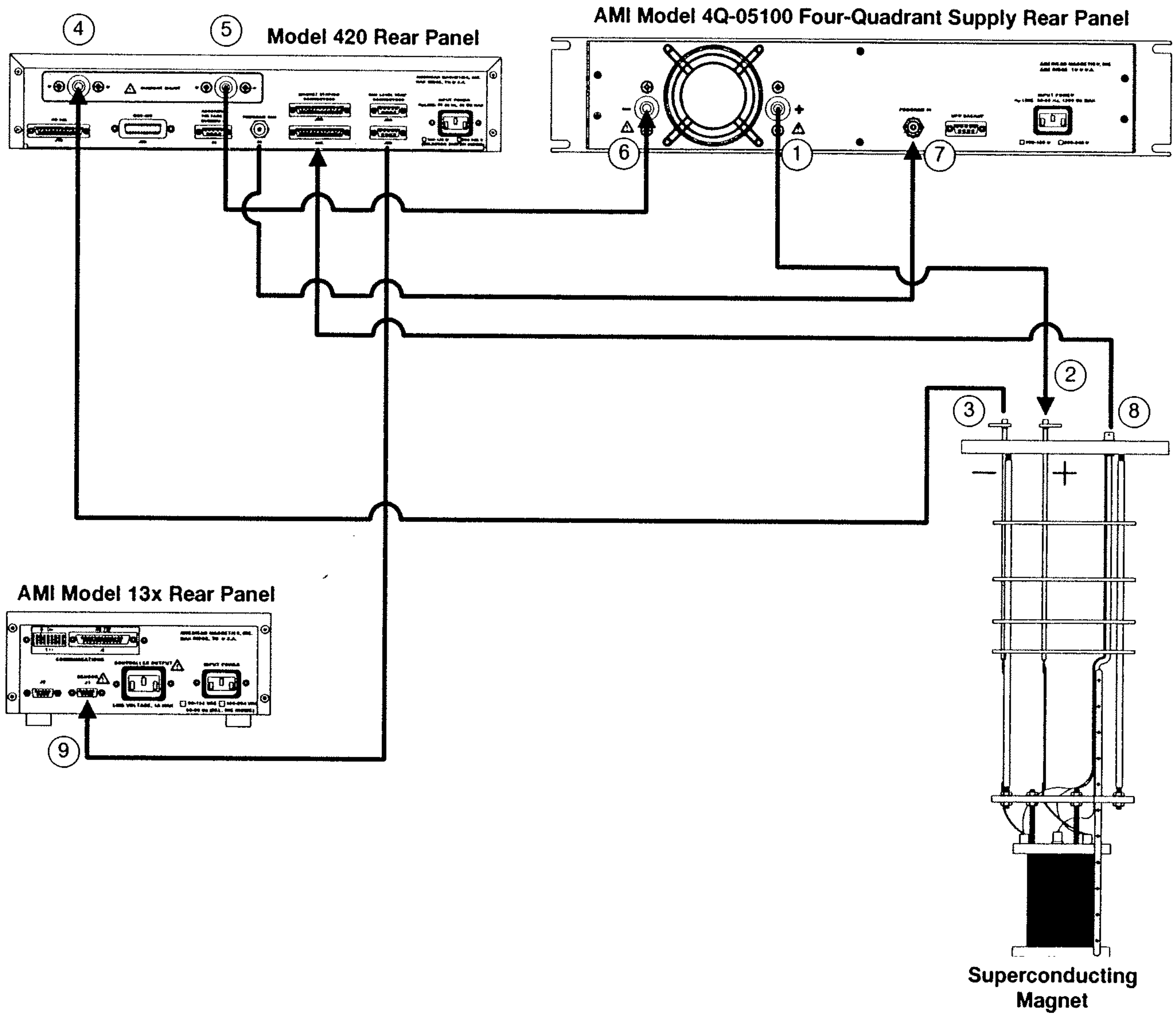
3. Connect the negative (–) shunt terminal (5) on the back of the Model 420 to the negative (–) power supply terminal (6).

4. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the **PROGRAM IN** connector (7) on the rear of the power supply.

5. Install an instrumentation cable between the magnet support stand top plate connector (8) and the magnet station connector J7A or J7B of the Model 420.

6. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x Liquid Helium Level Instrument and/or temperature instrument (9).

7. Remote communications via IEEE-488 and/or RS-232 (or optional RS-422) can be accomplished by connecting suitable cabling to J11 and/or J12 of the Model 420, respectively.



System interconnect diagram for the AMI Model 4Q-05100 power supply.

IV. OPERATION

A. During normal operation of the Model 4Q05100PS, no operator intervention is required.

B. The Model 4Q05100PS is operating if the **POWER** switch is in the ON (**I**) position. The output voltage may be monitored via the **Vs** display (commanded supply voltage) of the Model 420.

C. Control of the Model 4Q05100PS is achieved by using the AMI Model 420 Power Supply Programmer ramping functions.

The Model 4Q05100PS **PROGRAM IN** is a –10 to +10 VDC input, which controls the output voltage of the unit using a gain factor of 0.5.

⚠ ***WARNING:*** *Exercise caution near the supply output terminals on the rear of the unit when operating a magnet. Metallic objects shorted across the terminals may conduct large DC currents which are capable of melting the object and causing severe burns.*

D. The **OUTPUT INHIBIT** switch functions as an emergency override. The output of the Model 4Q05100PS is forced to zero volts by activating the switch. If the switch is deactivated, the **PROGRAM IN** signal controls the output voltage of the Model 4Q05100PS.

Turning off the AC mains is not recommended during non-persistent magnet operation since the overvoltage protection of the Model 4Q05100PS will activate and discharge the magnet at ±6 VDC. The **OUTPUT INHIBIT** switch is the preferred alternative in the event of a system malfunction.

NOTE: *Once the* **OUTPUT INHIBIT** *switch has been activated, the Model 420 will no longer have control of the magnet system current. Before attempting to recharge the magnet, cycle the Model 420 power (to first clear any states resulting from the open-loop configuration) and then deactivate the* **OUTPUT INHIBIT** *switch of the Model 4Q05100PS.*

V. MAINTENANCE

The only routine maintenance required is to keep the exterior surfaces of the instrument clean by gently wiping with a damp cloth moistened with a mild detergent. The front and rear panel vents of the Model 4Q05100PS should also be kept free of obstructions or excessive dust to allow for proper cooling of the unit.

VI. WARRANTY

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of a failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. All warranty repairs are F.O.B. Oak Ridge, Tennessee, USA.

VII. RETURN AUTHORIZATION

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive the proper attention. Please call an AMI representative at (865) 482-1056 for a return authorization before shipping any item back to AMI.

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MAGNET SYSTEM SPECIFICATIONS

AMI JOB #**9087** MAGNET #**9087**

Type: **Solenoid**

USER: **Dr. Syd Kreitzman**

FOR: **Triumf**

TEST DATE: **November 2, 2001**

Rated Central Field @ 4.2K --------------- **70 KG**

Rated Current ---------------------------- **77.2 Amps**

Maximum Test Field @ 4.2K * -------------- **72 KG**

Field to Current Ratio ------------------- **906.8 Gauss/Amp**

Homogeneity over 1 cm DSV ---------------- **+/-0.1%**

Best Effort Homogeneity over 6mm Dia x 2mm RCC -- **+/-0.002%**

Best Effort Field Decay ------------------ **<1x10E-6/Hr.**

Measured Inductance ---------------------- **12 Henrys**

Charging Voltage (Used in test) ---------- **2.0 Volts**

Axial Clear Bore ------------------------- **60 mm**

Tail Length (flange to flange) ----------- **10.0 inches**

Tail Width (flange to flange) ------------ **11.0 inches**

Magnet Weight ---------------------------- **26 lbs.**

Approx. System Weight -------------------- **300 lbs.**

Recommended Persistent Switch Heater Current --- **46 mA**

Persistent Switch Heater Nominal Resistance** -- **71 Ohms**

Magnet Resistance in Parallel with Switch** ---- **24 Ohms**

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Superconducting Shim Coil Field ---------------- **+/- 2 Gauss**

Superconducting Shim Coil Operating Current ---- **+/- 1 Ampere**

Horizontal Room Temp. Bore System

* Magnet not warranted for operation above **70 KG** field.

** All resistance measurements made at room temperature.

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#9087 MAGNET TEST DATA

The superconducting solenoid was tested on August 17, 2001 prior to installation into the cryostat, and again on November 2, 2001 after installation into the cryostat. The magnet experienced no training during any of the tests. Listed below are the test results:

8/17/01 Ramped up to 72 kG at 2 volts in about 10 minutes. No quench.

8/17/01 Ramped down to 70 kG at 2 volts, locked in persistent switch. While locked in @ 70KG, injected +/-2 amperes in the shim coils.

8/17/01 Ramped magnet down to zero field and prepared for shipment to dewar vendor.

11/1/01 Received dewar / magnet, noted weld bead in bore tube and advised customer & dewar vendor.

11/2/01 Wiring pin out verification. LN2 transferred to LHe chamber with off gas vented to LN2 chamber. Inserted LN2 blow out tube, LN2 blown out of LHe chamber into LN2 chamber (~2 psi helium gas). Filled LHe chamber with LHe (~31" LHe). Ramped magnet (2V) to 70KG, locked in switch, injected +/-1 amperes in shim coils. Ramped magnet down to 30KG & locked in switch. Power supply ramped to zero, VCCL's raised (~3").

11/3/01 ←→ 11/8/01 Watched loss rates, mapped field and tried to get magnet to drift down. 11/5/01 5:02pm ←→ 11/6/01 9:03am LHe went from 22.1" to 20.1" with 16.75" ID helium chamber = ~0.23 L/hr. Field map emailed to customer (Volume2.xls & Volume3.xls). Drift rate never determined, but tending in correct direction.

11/8/01 AMI filed out dewar bore for 60mm clear.

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OPERATING INSTRUCTIONS

I. Initial Cool down of Magnet with LN2

1.) It is a good idea to monitor the cool down of the system by measuring resistance change across the current leads.
2.) Insert the 3/8" OD stainless steel cool down/blowout tube (~29" Long) into the 3/8" LHe fill port (labeled "F") located on the top plate of the dewar. Cool down/blowout tube should be raised so it is ~3 inches above seat.
3.) Replace dewar neck KF40 block off plate with block off plate that has 3/8" OD tube welded to it (labeled "K").
4.) Remove a plug from the LN2 jacket and insert short (G-10) 3/8" OD tube (labeled "Short"). Remove the other LN2 jacket plug for venting of nitrogen gas.
5.) Attach rubber hose from "Short" to "K".
6.) Pinch shut both VCCL's rubber hoses.
7.) Begin flowing LN2 into the LHe reservoir through the 3/8" OD tube.
8.) Continue filling with LN2 until the magnet is completely submerged.
9.) Allow system to cool (~3 hrs.).

II. Blowout of LN2 from Liquid Helium Reservoir

1.) Disconnect the LN2 hose from the LN2 supply dewar.
2.) Screw in the (~29" Long) cool down/blowout tube into the 3/8" LHe fill port (labeled "F").
3.) LN2 removed from the LHe reservoir can be used to directly fill the nitrogen jacket. Connect the hose from the LN2 cool down/blowout tube (~29" Long) to one of the LN2 dewar jacket ports.
4.) Pressurizing either through the current lead off gas fitting ("+" or "-"), or through the KF40 ("K" this is the preferred way) flange located on the side of the dewar neck. Use either nitrogen or helium gas for pressure (~2psi←→3psi).

Note: It is important that all LN2 is removed from the cryostat before cooling the magnet and cryostat to 4.2K. Removing all residual LN2 can be accomplished by allowing the system to warm up several degrees above 77K to evaporate any LN2.

5.) LN2 jacket should be filled until LN2 is seen to spit out of the LN2 venting port.
6.) Stop LN2 transfer and replace both LN2 jacket aluminum port plugs.

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III. Initial LHe Fill

1.) Remove the 3/8" OD tube from the LHe fill port ("F").
2.) Replace the KF40 flange with the tube welded to it ("K") with the KF40 blank flange (labeled "B").
3.) Connect a 3/8" OD LHe transfer line to the LHe fill port ("F") and ensure that it is inserted until it stops.
4.) Slowly transfer LHe into the cryostat until the system is cooled to 4.2K and the LHe begins to collect in the cryostat. This will be evident from your cool down monitoring (resistance goes flat) or from your LHe level meter showing collection. The most efficient transfer rate is one where there is a light flow of vapor venting from the cryostat.
5.) Vent some of the exhausting helium gas through the vapor cooled current leads to prevent blocking the gas vent holes with condensing moisture and freezing air.
6.) As soon as the dewar temperature reaches 4.2K and LHe begins to collect in the cryostat, the exhaust gas should decrease noticeable. The transfer rate can be increased at this point without excessive helium loss.
7.) Once the desired LHe level is reached, stop the LHe transfer, remove the transfer line and cap the transfer fill port ("F").

IV. Preparing for Magnet Operation

1.) Setup the power supply system. Refer to the documentation provided with the power supply system.
2.) Ensure that the breakaway vapor cooled current leads are engaged. This can be accomplished by loosening the brass Swagelock fitting and pushing down on the current leads and making sure they have "bottomed out". It may be easiest to engage them one at a time.
3.) Connect the power supply cables to the vapor cooled current leads, making sure the polarities match.
4.) The AMI Model 420 programmer has been pre-set at the factory for this specific magnet. Verify that the Model 420 matches the factory configuration as listed in this documentation.
5.) If necessary, adjust the programmer/power supply system controls in accordance with the supplied manuals.
6.) The magnet is ready for operation. Please refer to the power supply system documentation for specific instructions

AMI SUPERCONDUCTING MAGNETS

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

Addendum to Revision 3 Manual, Installation section, Instrumentation and control check:

CAUTION:
Some non-AMI programmer/power supply systems are capable of producing voltages up to 30 volts and more than a 100 amperes. These power supplies can easily exceed the turn-on voltages of protective diodes on superconducting magnets. Furthermore, these power supplies may not always turn off when a quench occurs in a superconducting magnet. The result is that these power supplies can drive more than 100 amperes through the quench protection diodes on the magnet for an extended period of time causing diode failure. This is especially disastrous if the magnet is welded in a dewar. The dewar must then be cut apart to get the magnet out and replace the protection diodes. AMI programmer/power supply systems are very good at detecting quenches and are designed, in conjuction with an energy absorber, to limit the magnet voltage to less than 5 volts. If you use another vendor's power supply system, AMI cannot assume any liability for the costs associated with cutting the dewar apart and repairing the magnet if AMI determines that the problem was caused by the non-AMI power supply system.

EXCELLENCE IN MAGNETICS AND CRYOGENICS

AMI SUPERCONDUCTING MAGNETS

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

American Magnetics, Inc.

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Rev. 4, September 1996

Introduction

These instructions are written to be generic and apply to most of the various types of magnets supplied by AMI. Some sections and data may or may not apply to the system you have purchased. It is recommended that you carefully read these instructions prior to the installation and operation of your magnet system. If you have purchased a magnet that is permanently installed into a cryostat, these instructions will generally be supplemented by operating instructions provided by the cryostat manufacturer.

Magnet Construction

AMI superconducting magnets are typically wound using conductors comprised of many filaments of a superconducting material embedded in a copper matrix and twisted along its axis to insure optimum performance of the superconductor. Electrical insulation is provided by the insulation on the wire and by the epoxy between each turn. All magnets are wet wound or vacuum impregnated with an epoxy to assure the absence of voids and to prohibit movement of the wire.

The former on which the magnet is wound is constructed of aluminum, brass, stainless steel, or other material as required for a particular magnet. Micarta end flanges are typically used on the magnets to provide a rugged, insulated mounting surface. When required, tapped brass inserts are screwed and epoxied into the end flange for supporting the magnet. Standard mounting holes are tapped for threaded rods or screws. Current lugs, protective diodes, and a persistent switch are typically mounted on one end of the magnet.

AMI magnets are typically over-wrapped with a yellow cord to protect the windings from minor shock. The end flanges are painted dark blue and each magnet is labeled with a unique four digit serial number.

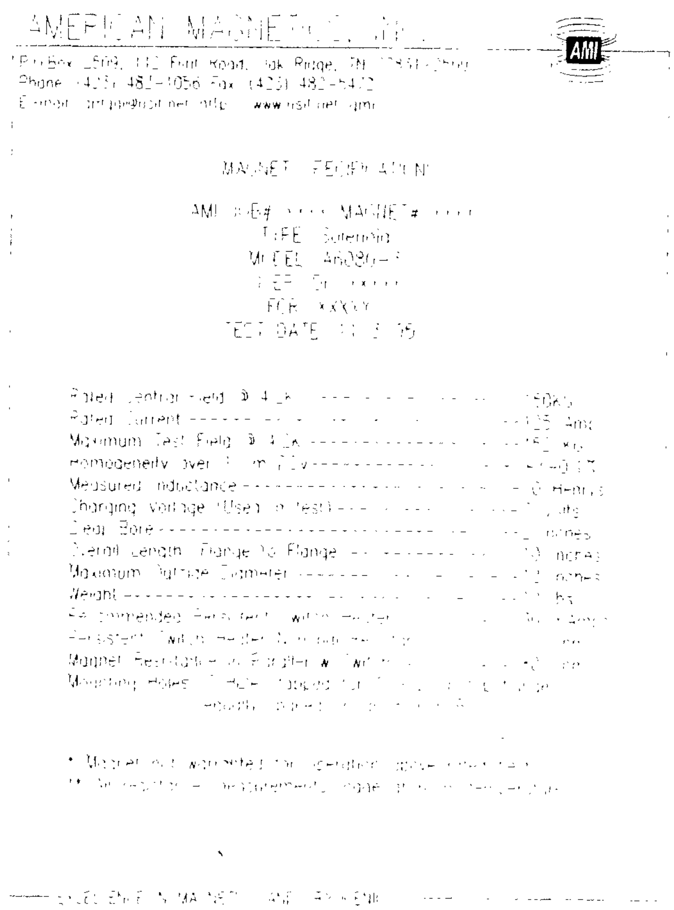
Specifications

A *Magnet Specification Sheet* is provided with each magnet after it has been tested at AMI. All stated currents are nominal and may vary slightly from the cited currents in the final magnet application. The coil constant which specifies the magnetic field produced per ampere of current is supplied with each magnet.

Magnet Protection

All AMI magnets are designed and constructed such that in the unlikely event of a quench at fields up to and including the rated field, damage will not occur to the magnet. Each magnet is warranted against such damage by the standard AMI warranty. AMI magnets are not warranted if operated above the rated field.

Specifications



The above diagram is an example of a typical *Magnet Specification Sheet*. The specifications for the magnet are mailed to the customer and a copy is included with the magnet shipment.

The following is an explanation of typical magnet specification parameters as they appear on the *Magnet Specification Sheet*. Some specifications are unique to a particular magnet type and the data may not appear on your sheet or additional data may be added as appropriate.

1. **Rated Field @4.2K** - The rated field is the maximum field the magnet is guaranteed to achieve and be protected. The rated field is verified by nuclear

15. **Magnet Resistance in Parallel with Switch** - Magnet resistance in parallel with switch is the room temperature resistance of the magnet windings and the switch in parallel.

16. **Mounting Holes** - The mounting hole specification is the magnet mounting method and geometry.

Table of Contents

1 Installation

Unpack the magnet

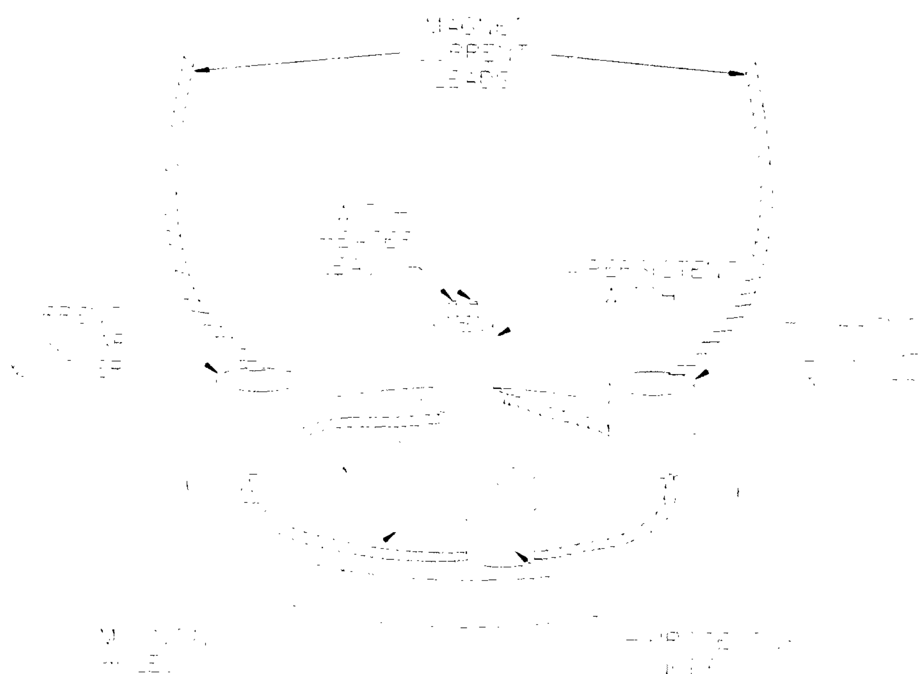
Carefully remove the magnet from the shipping carton and remove all packaging material. Inspect all contents for any damage that may have occurred during shipment.

Note

If there is any shipping damage, save all packing material and contact the shipping representative to file a damage claim. Do not return the magnet to AMI unless prior authorization has been received.

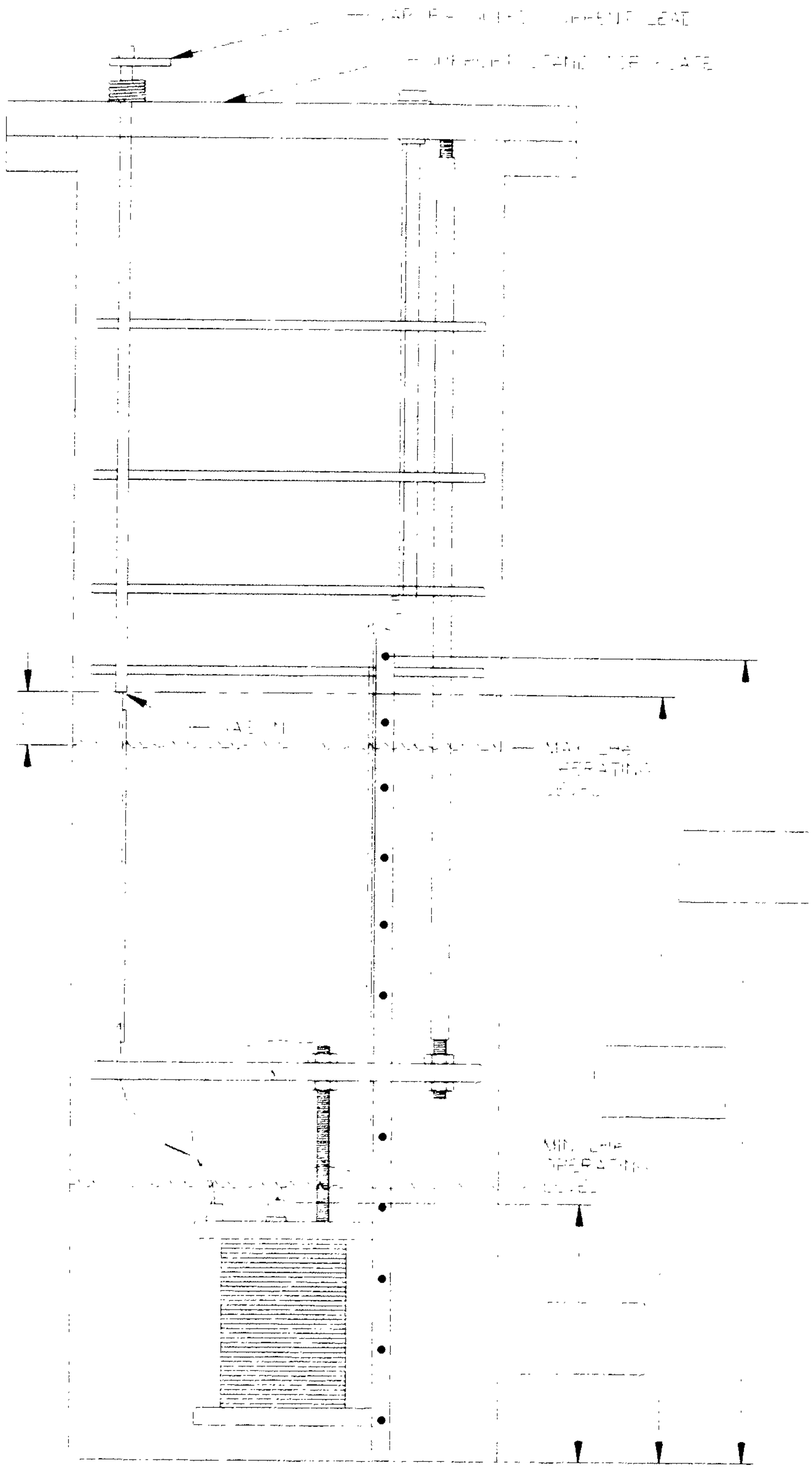
Setup

1. Mount the magnet on the support stand or other device that will support the magnet in the dewar.



Caution

Be careful not to overtighten the mounting screws in the mounting lugs to prevent damage to the threads.



Note

An 18-24" piece of tubing, connected to the top vent of each lead, and allowed to hang over the side of the dewar is an effective way to create a helium gas trap and minimize the air which enters the leads.

4. It is advisable to monitor the magnet temperature during LHe transfer to make sure proper cooldown is taking place. Cooldown can be simply monitored by measuring the resistance of the magnet. LHe will not collect in the dewar until the dewar and magnet temperature reaches 4.2K. Adjust the storage dewar pressure for the proper transfer rate best indicated by observing the helium gas exiting from the dewar vent. The most efficient transfer rate is one where there is a light flow of vapor from the vessel vent. If the vapor has significant pressure or spits and sputters, the transfer rate is excessive and should be reduced.

Note

A transfer tube with a poor vacuum or thermal short can evaporate all the liquid helium before it reaches the dewar.

5. As soon as the dewar temperature reaches 4.2K and liquid helium begins to collect in the bottom of the dewar, the exhaust gas should decrease noticeably. The transfer rate can be increased at this point without excessive helium loss.

6. Once the desired LHe level is reached, stop LHe transfer, remove the transfer line and cap the transfer port.

Instrumentation and control check

Prior to connecting the power supply cables to the vapor-cooled current leads, the power supply system should be checked for proper control and indication.

1. Setup the power supply system. Refer to the documentation provided with the power supply system.

Caution

⚠ *Make sure the power supply and magnet controller is installed in accordance with the operating instruction provided with your magnet current programmer.*

Caution

Some non-AMI programmer/power supply systems are capable of producing voltages up to 30 volts and more than a 100 amperes. These power supplies can easily exceed the turn-on voltages of protective diodes on superconducting magnets. Furthermore, these power supplies may not always

2 Operation

Energizing the magnet

1. If the magnet is equipped with a persistent switch, make sure the persistent switch heater power supply is switched on and is supplying the appropriate current to the switch heater. This current value is recorded on the Magnet Specification Sheet provided with the magnet.

   Caution

   ⚠ *Only operate the magnet when completely immersed in liquid helium. Failure to do so may result in magnet and/or system damage.*

2. Adjust all programmer/ power supply system controls in accordance with their respective manuals for system start-up.

3. Set the programmer/ power supply system current limit setpoint to the desired current level but not to exceed the rated current value recorded on the Magnet Specification Sheet. Make sure the programmer ramp controls are in the 'down' position.

4. Energize the programmer/ power supply system.

5. Set the programmer to the appropriate ramp rate.

6. Verify the programmer/ power supply system stabilizes the magnet current at the rated current level.

   Caution

   ⚠ *It is important to always limit the current level of the magnet to never exceed the rated current recorded on the Magnet Specification Sheet. Exceeding the rated current specification may void the magnet warranty and may cause damage to the magnet in the event of a magnet quench.*

   Caution

   ⚠ *During non-persistent magnet operation, the flow through the vapor-cooled current leads should be checked and balanced to achieve approximately equal flow thru each lead. Balancing may be achieved by slightly restricting the flow through the lead with the higher flow. Operation of vapor cooled current leads with inadequate flow could result in lead damage.*

current level differences may cause the programmer/ power supply system to interpret the equalizing voltage as a magnet quench.

Deenergizing the magnet

Ramp the magnet current to zero using the programmer/ power supply system.

When the current in the magnet and the voltage across the magnet reaches zero, the magnet is de-energized.

System shutdown

1. After the magnet has been de-energized, any desired instrumentation and the programmer/ power supply system may be shutdown.

2. Prior to disconnecting cables from the dewar top plate, make sure the programmer/ power supply system and axillary instrumentation are de-energized.

Warning

Superconducting magnets have the capability to store large amounts of energy and can be dangerous and potentially fatal. Make sure the magnet is completely discharged and all electronics are de-energized before performing any disassembly.

Exercise caution when handling materials which are at cryogenic temperatures. Severe burns could result to unprotected skin.

Caution

Use care in handling cold cabling, sensors, etc., since these items usually become very brittle at LHe temperatures and may be damaged if not handled carefully.

3. To minimize condensation internal to the dewar when allowing the magnet to warm-up, close all openings except the outlet of the vapor-cooled current leads (which should have helium gas traps).

4. Warm helium gas may be pumped in to speed up the process. More openings may need to be provided if gas outflow becomes to large.

3 Troubleshooting

The following troubleshooting aids are included to assist he user in identifying and correcting magnet system problems. In the event that the trouble cannot be corrected, please contact an AMI representative for assistance.

Magnet not charging

1. Voltage indicated on power supply; *No* voltage developed across magnet.

    a. Make sure the programmer/ power supply system has been setup and tested in accordance with the respective manuals. Specifically the installation section of this manual which entails operating the power supply system

    b. Check all connections for proper contact and connection. Voltage present with no current flow is indicative of an open circuit.

    c. Make sure the power supply current leads are securely connected to the vapor-cooled current leads with no ice or debris between the contact points.

    d. If using an polarity switching energy absorber in the power supply system, make sure the energy absorber is properly energized.

    e. If the current ramps up and no voltage developed across magnet, make sure the persistent switch heater is properly energized and the proper amount of current is flowing through the persistent heater. The persistent switch heater current specification and the magnet inductance specifications are recorded on the Magnet Specification Sheet. The voltage across the magnet is governed by the equation $E = L * (dI/dt)$. Make sure the proper current is flowing to the persistent switch and the proper connections are made. If the problem continues, investigate a short circuit across the magnet.

    f. If voltage is present at the magnet leads but minimal current flows, the magnet may not be at 4.2K. Make sure the liquid helium level is above the magnet and the helium boil-off has stabilized at the expected level. Also, physical damage to the magnet wires may cause these symptoms. If this magnet damage is a possibility, call AMI and speak with a sales representative.

2. *No* voltage indicated on power supply; *No* voltage developed across magnet.

    a. Make sure the programmer/ power supply system has been setup and tested in accordance with the respective manuals.

4 Warranty/Return Authorization

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. Since, however, AMI does not have control over the installation conditions or the use to which its products are put, no warranty can be made of fitness for a particular purpose, and AMI cannot be liable for special or consequential damages. All warranty repairs are F.O.B. Oak Ridge, Tennessee, USA.

Return Authorization

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to make sure your order will receive proper attention. Please call an AMI representative at (865) 482-1056 for a return authorization number before shipping any item back to the factory.

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Declaration of Conformity

Application of Council Directive:	72/73/EEC
Standard to which Conformity is Declared:	EN 61010-1: 1993 w/A1, A2
Manufacturer's Name:	American Magnetics, Inc.
Manufacturer's Address:	112 Flint Road, P.O. Box 2509 Oak Ridge, TN 37831-2509 U.S.A.
Type of Equipment:	Liquid Helium Level Instruments
Model Numbers:	Model 135 and 136

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive and Standard.

Place:	Oak Ridge, Tennessee, U.S.A.	Signature:	Charles Hargis
Date:	October 15, 1999	Full Name:	Charles H. Hargis
		Function:	Quality Assurance Manager

MODEL 135/136 LIQUID HELIUM LEVEL INSTRUMENT

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

American Magnetics, Inc.

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Rev. 3, December 2000

Instrument Configuration

AMI Order Number:____________________ Shipping Date:____________________

Model/Serial #:____________________ Firmware Revision:____________________

Input Power Requirements:____

Configuration Notes:

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AMI Warranty

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. Since, however, AMI does not have control over the installation conditions or the use to which its products are put, no warranty can be made of fitness for a particular purpose, and AMI cannot be liable for special or consequential damages. All warranty repairs are F.O.B. Oak Ridge, Tennessee, USA.

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Foreword

Purpose and Scope

This manual contains the operation and maintenance instructions for the American Magnetics, Inc. Model 135/136 Liquid Level Instrument. The manual outlines the instructions for instrument use in various system designs. Since it is impossible to cover all possible system/sensor designs, the most common configuration is discussed and the user is encouraged to contact an authorized AMI Technical Support Representative for information regarding specific configurations not explicitly covered in this manual.

Contents of This Manual

Introduction introduces the reader to the functions and characteristics of the instrument. It provides the primary illustrations of the front and rear panel layouts as well as documenting the performance specifications.

Installation describes how the instrument is unpacked and installed in conjunction with ancillary equipment in a typical cryogenic system.

Operation describes how the instrument is used to measure and control liquid level. *All* instrument controls are documented.

Remote Interface Reference documents all remote commands and queries available through the serial and IEEE-488 interfaces. A quick-reference summary of commands is provided as well as a detailed description of each.

Service provides guidelines to assist Qualified Service Personnel in troubleshooting possible system and instrument malfunctions. Information for contacting AMI Technical Support personnel is also provided.

The ***Appendix*** documents the rear panel connectors.

Applicable Hardware

The Model 135/136 has been designed to operate with an AMI Liquid Helium Level Sensor. Operation with other equipment is not recommended and may void the warranty.

General Precautions

Cryogen Safety

Personnel handling cryogenic liquids should be thoroughly instructed and trained as to the nature of the liquids. Training is essential to minimize accidental spilling. Due to the coldness of these materials, a cryogen spilled on many objects or surfaces may damage the surface or cause the object to shatter, often in an explosive manner.

Inert gases released into a confined or inadequately ventilated space can displace sufficient oxygen to make the local atmosphere incapable of sustaining life. Cryogenic liquefied gases are potentially extreme suffocation hazards since a small amount of liquid will vaporize and yield a very large volume of oxygen-displacing gas. Always ensure the location where the cryogen is used is well ventilated. Breathing air with insufficient oxygen content may cause unconsciousness without warning. If a space is suspect, purge the space completely with air and test before entry. If this is not possible, wear a forced-air respirator and enter only with a co-worker standing by wearing a forced-air respirator.

Cryogenic liquids, due to their extremely low temperatures, will burn the skin in a similar manner as would hot liquids. Never permit cryogenic liquids to come into contact with the skin or allow liquid nitrogen to soak clothing. Serious burns may result from careless handling. Never touch uninsulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures. The vapors expelled during the venting process are sufficiently cold to burn flesh or freeze optic tissues. Insulated gloves should be used to prevent frost-bite when operating valves on cryogenic tanks. Be suspicious of valves on cryogenic systems; the extremes of temperature they undergo causes seals to fail frequently.

In the event a person is burned by a cryogen or material cooled to cryogenic temperatures, the following first aid treatment should be given pending the arrival and treatment of a physician or other medical care worker:

1. If any cryogenic liquid contacts the skin or eyes, immediately flush the affected area gently with tepid water (102°F – 105°F, 38.9°C – 40.5°C) and then apply cold compresses.

2. Do not apply heat. Loosen any clothing that may restrict circulation. Apply a sterile protective dressing to the affected area.

3. If the skin is blistered or there is any chance that the eyes have been affected, get the patient immediately to a physician for treatment.

Containers of cryogenic liquids are self pressurizing (as the liquid boils off, vapor pressure increases). Hoses or lines used to transfer these liquids should never be sealed at both ends (i.e. by closing valves at both ends).

When pouring cryogenic liquids from one container to another, the receiving container should be cooled gradually to prevent damage by thermal shock. The liquid should be poured slowly to avoid spattering due to rapid boil off. The receiving vessel should be vented during the transfer.

Introduction of a substance at or near room temperature into a cryogenic liquid should be done with great caution. There may be a violent gas boil off and a considerable amount of splashing as a result of this rapid boiling. There is also a chance that the material may crack or catastrophically fail due to forces caused by large differences in thermal contraction of different regions of the material. Personnel engaged in this type of activity should be instructed concerning this hazard and should always wear a full face shield and protective clothing. If severe spraying or splashing could occur, safety glasses or chemical goggles along with body length protective aprons will provide additional protection.

The properties of many materials at extremely low temperatures may be quite different from the properties that these same materials exhibit at room temperatures. Exercise extreme care when handling materials cooled to cryogenic temperatures until the properties of these materials under these conditions are known.

Metals to be used for use in cryogenic equipment application must posses sufficient physical properties at these low temperatures. Since ordinary carbon steels, and to somewhat a lesser extent, alloy steels, lose much of their ductility at low temperatures, they are considered unsatisfactory and sometimes unsafe for these applications. The austinetic Ni-Cr alloys exhibit good ductility at these low temperatures and the most widely used is 18-8 stainless steel. Copper, Monel®, brass and aluminum are also considered satisfactory materials for cryogenic service.

Safety Summary

Cryogenic storage systems are complex systems with the potential to seriously injure personnel or equipment if not operated according to procedures. Proper use of safety mechanisms (pressure relief valves, rupture disks, etc.) included in the cryostat and top plate assembly are necessary.

Recommended Safety Equipment

- First Aid kit
- Fire extinguisher rated for class C fires
- Leather gloves
- Face shield
- Signs to indicate that there are potentially dangerous cryogens in use in the area.

Safety/Manual Legend

Instruction manual symbol: the product is marked with this symbol when it is necessary for you to refer to the instruction manual in order to protect against damage to the product or personal injury.

Hazardous voltage symbol.

Alternating Current (Refer to IEC 417, No. 5032).

Off (Supply) (Refer to IEC 417, No. 5008).

On (Supply) (Refer to IEC 417, No. 5007).

Warning

The Warning sign denotes a hazard. It calls attention to a procedure or practice, which if not correctly adhered to, could result in personal injury. Do not proceed beyond a Warning sign until the indicated conditions are fully understood and met.

Caution

The Caution sign denotes a hazard. It calls attention to an operating procedure or practice, which if not adhered to, could cause damage or destruction of a part or all of the product. Do not proceed beyond a Caution sign until the indicated conditions are fully understood and met.

Model 136 This marking in the left margin of the manual designates a feature, procedure, or specification that is unique to the Model 136.

1 Introduction

1.1 Model 135/136 Features

The American Magnetics, Inc. (AMI) Model 135/136 Liquid Helium Level Instrument is an advanced, microprocessor-based instrument utilizing AMI's patented sample-and-hold principle with automatic helium sensor vacuum burnout protection. The instruments are designed for unattended operation in systems where it is important to monitor and/or control the liquid helium levels and minimize the liquid helium losses.

The Model 135/136 is designed to be used in conjunction with an AMI liquid helium level sensor. The liquid helium level sensor consists of a small diameter NbTi filament in a hollow tube. A constant current is passed through this filament causing the portion of the filament in helium gas to become resistive, while the portion in the liquid helium remains superconducting. The resulting voltage across the resistive portion of the filament is read by the instrument, converted to a liquid level, and displayed on the front panel LED display.

1.1.1 Minimal liquid helium losses

In order to minimize liquid helium loss, the Model 135/136 automatically energizes the liquid helium level sensor at predetermined time intervals and monitors the normal (resistive) zone as it progresses from the top of the sensor toward the surface of the liquid helium. As soon as the normal zone reaches the liquid surface the level reading is saved and the sensor current is turned off until the next sample interval occurs. The SENSOR CURRENT LED is illuminated during each sample. Sample intervals are user programmable from the front panel and can be set between 0.0 (no delay between samples) to 600.0 minutes or hours. A sampling mode toggle switch provided on the front panel can be toggled for continuous readings during a helium transfer period or for just a quick level reading update.

1.1.2 Automatic Level Control

Model 136

The Model 136 provides automatic level control capabilities. Two independent setpoints, A and B, are provided for determining a control band to activate/deactivate a power receptacle on the rear panel. The Model 136 is designed for unattended operation in systems where automated refills are required.

1.1.3 Burnout protection

The Model 135/136 provides automatic helium sensor vacuum burnout protection. A sensor which is energized in a vacuum environment without contact with liquid helium will self-heat to the point of burnout. AMI's innovative microprocessor-based circuitry detects incipient sensor burnout and de-energizes the sensor before damage can occur. A 5% increase in sensor resistance will trigger this protection, causing the current to be switched off for 6 seconds before attempting to resume normal operation.

1.1.4 Floating supply

Due to safety concerns, the high voltage power supply used for the sensor is a floating supply. This minimizes the possibility of personal injury in the inadvertent event of someone who is grounded coming in contact with the energized sensor electrical wires.

1.1.5 Convenient display

The Model 135/136 is equipped with a 4-digit LED digital display which provides liquid helium level indication in inches, centimeters or percent as selected by a front panel switch. A front panel switch allows the user to adjust the instrument quickly and easily for any length sensor up to 80 inches (203 cm). The sensor active length can be entered in either inches or centimeters.

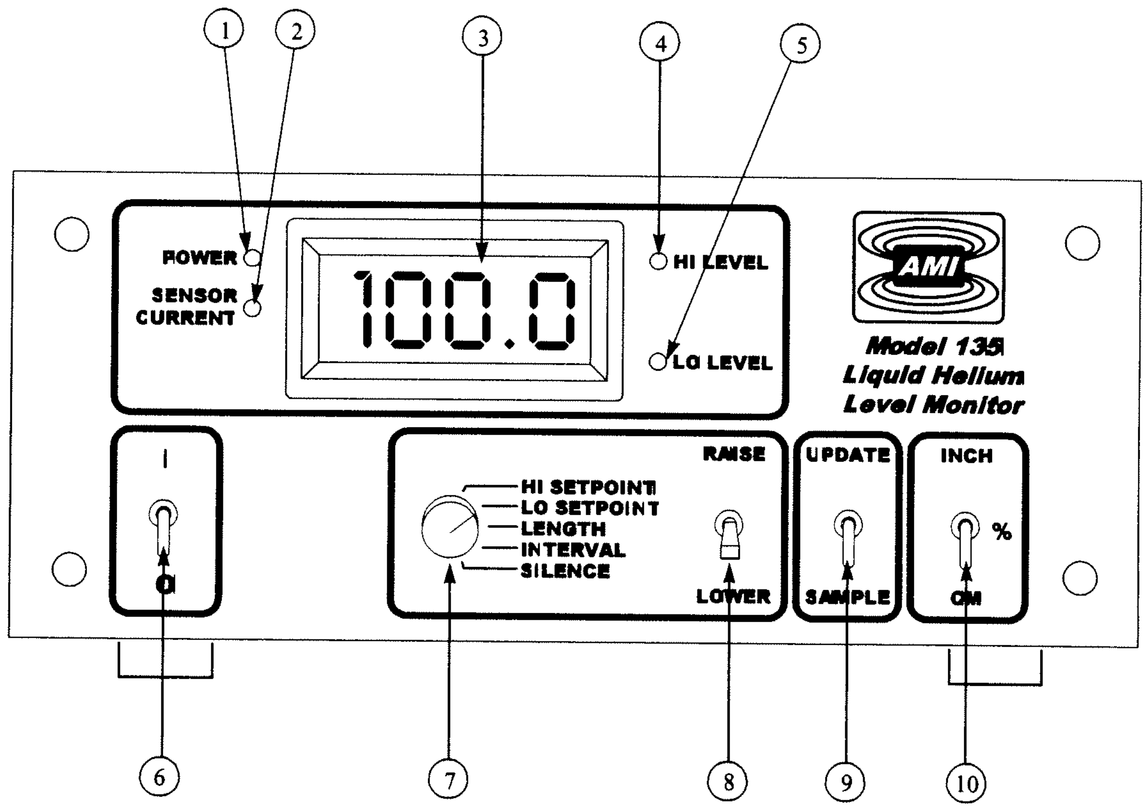
1.1.6 Microprocessor-based electronics

Microprocessor-based electronics provide 0.1% readout accuracy. Nonvolatile memory maintains instrument calibration without battery backup. Watchdog timer circuitry and low line voltage (brownout) detector prevent microprocessor lockup and provide fail-safe operation.

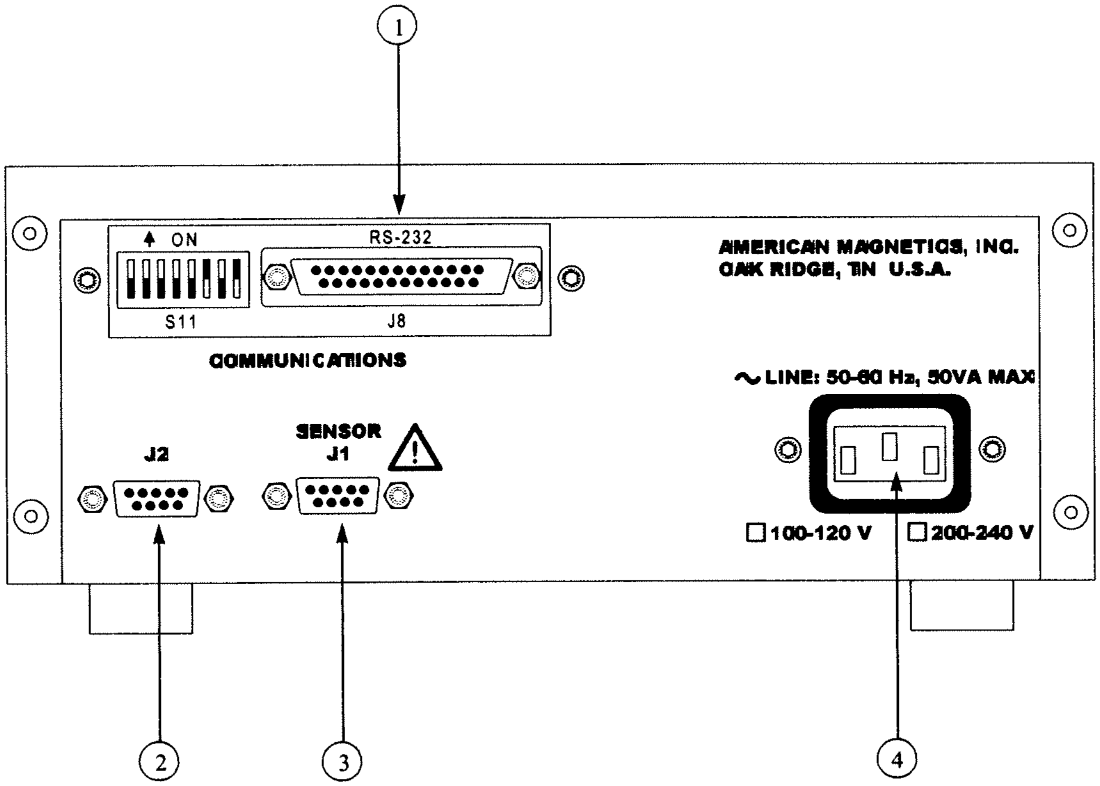
1.1.7 Remote computer monitoring or controlled operation

The Model 135/136 is provided with a 0-10 volt recorder output. A 4-20 mA current loop option is available in lieu of the recorder output. Available computer interface options include RS-232/422 Serial Port/Data Logger or IEEE-488.

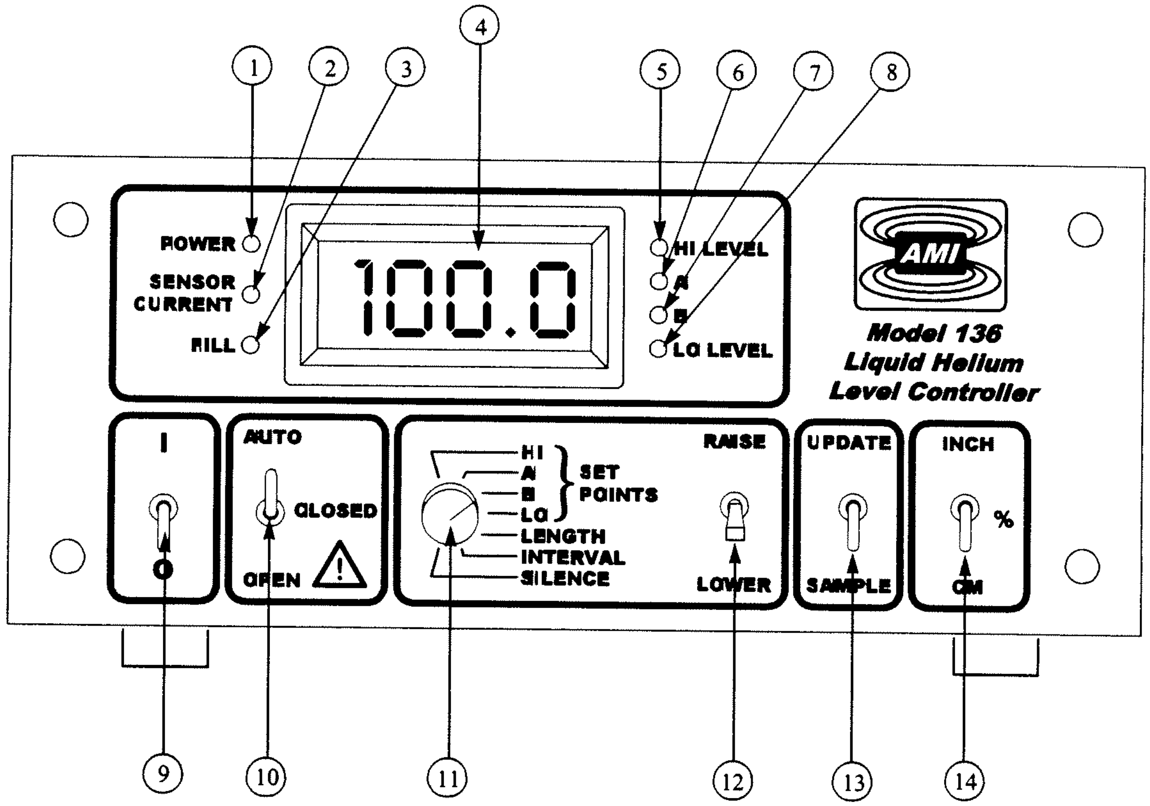
The Model 135/136 may be optionally configured for a maximum of one analog output option and one computer interface option.



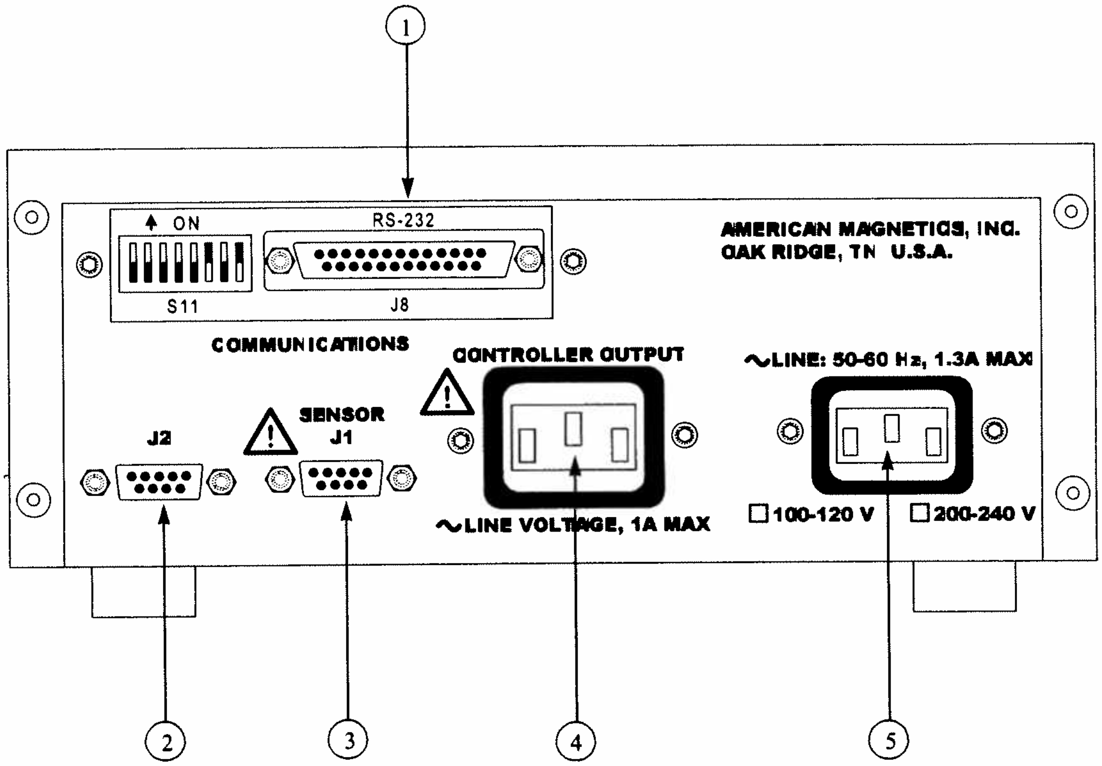
1	Power ON LED	**6**	Power toggle switch
2	Sensor current LED	**7**	Control mode rotary switch
3	LED level display	**8**	Raise/lower toggle switch
4	Hi level LED	**9**	Sampling mode toggle switch
5	Lo level LED	**10**	Units mode toggle switch



1	Optional RS-232 or GPIB communications port (RS-232 shown)	**3**	Sensor input DB-9 female connector (see the *Appendix* for the pinout diagram)
2	Auxiliary DB-9 male connector (see *Appendix* for pinout)	**4**	Power cord connector



1	Power ON LED	**8**	Lo level LED
2	Sensor current LED	**9**	Power toggle switch
3	Fill indication LED	**10**	Fill toggle switch
4	LED level display	**11**	Control mode rotary switch
5	Hi level LED	**12**	Raise/lower toggle switch
6	A level LED	**13**	Sampling mode toggle switch
7	B level LED	**14**	Units mode toggle switch



1	Optional RS-232 or GPIB communications port (RS-232 shown)	**4**	Controller output receptacle
2	Auxiliary DB-9 male connector (see *Appendix* for pinout)	**5**	Power cord connector
3	Sensor input DB-9 female connector (see the *Appendix* for the pinout diagram)		

1.6 Model 135/136 Specifications @ 25 °C

Level Measurements

	Resolution:	0.1%, 0.1 cm, or 0.1 in
	Accuracy[a]:	± 0.5% of active sensor length
	Linearity:	± 0.1%
	Sensor Current:	75 mA nominal
	Sensor Voltage:	approx. 70 VDC for 80" active sensor length

Operating Parameters

	HI and LO Alarms:	0% to 100% adjustable
	HI/LO Alarm Relay Contact Ratings:	10 VA, 30 VAC or 60 VDC, 0.5 A (normally open, closed on alarm)
	Sample-and-Hold Period:	0.1 to 600.0 minutes or hours
Model 136	A and B Control Setpoints:	0% to 100% adjustable
Model 136	Controller Output:	AC line voltage @ 1A max current
Model 136	Fill Timer:	0.1 to 600.0 minutes or hours

0-10 Volt Analog Output

	Integral Non-linearity:	± 0.012%
	Resolution:	16 bits
	Total Error:	± 1.1% for 0-10 V output
	Voltage Drift (0-10 V):	100 ppm / °C

4-20 mA Analog Output @ 24 V

	V_{ext} Supply Range:	13-32 VDC (see *Appendix* for diagram)
	Integral Non-linearity:	± 0.012%
	Resolution:	16 bits
	Total Error:	± 0.25% for 4-20 mA output
	Current Drift (4-20 mA):	75 ppm / °C
	PSRR:	10 µA / V

Power Requirements

	Primary[b]:	100-120 or 200-240 VAC ±10% 50 - 60 Hz
	Maximum Current:	50 VA for Model 135 1.3 A for Model 136

Physical		
	Dimensions (Standard):	97 mm H x 213 mm W x 273 mm D (3.8" H x 8.4" W x 10.75" D)
	Weight (Standard):	1.8 kg (4.0 lbs.) for Model 135 2.0 kg (4.3 lbs.) for Model 136
	Dimensions (Rack Mount):	89 mm H x 483 mm W x 273 mm D (3.5" H x 19" W x 10.75" D)
	Weight (Rack Mount):	2.3 kg (5.0 lbs.)
Environmental		
	Ambient Temperature:	Operating: 0 °C to 50 °C (32 °F to 122 °F) Nonoperating: –20 °C to 60 °C (–4 °F to 140 °F)
	Relative Humidity:	0 to 95%; non-condensing

a. Under extreme radiated electromagnetic field conditions (3V/m at 150 MHz to 170 MHz), the accuracy may be degraded to an absolute error of ±0.3 cm.
b. Maximum active sensor length is limited to 64 inches for input line voltages below 105 VAC or 210 VAC.

2 Installation

Warning

Before energizing the instrument, the earth ground of the power receptacle must be verified to be at earth potential and able to carry the rated current of the power circuit. Using extension cords should be avoided; however, if one must be used, ensure the ground conductor is intact and capable of carrying the rated current.

In the event that the ground path of the instrument becomes less than sufficient to carry the rated current of the power circuit, the instrument should be disconnected from power, labeled as unsafe, and removed from place of operation.

Do not operate this instrument in the presence of flammable gases. Doing so could result in a life-threatening explosion.

Do not modify this instrument in any way. If component replacement is required, return the instrument to AMI facilities as described in the Service section of this manual.

If the instrument is used in a manner not specified by AMI, the protection provided by the equipment may be impaired.

2.1 Unpacking the Instrument

Carefully remove the instrument, sensor, and interconnecting coaxial cables from the shipping carton and remove all packaging material. A rack mounting kit is supplied if the instrument was purchased with the rack mount option.

Note

If there is any shipping damage, save all packing material and contact the shipping representative to file a damage claim. Do not return the instrument to AMI unless prior authorization has been received.

If the chassis is a table top model, place the instrument on a flat, secure surface.

2.2 Rack Mounting the Instrument

If the instrument has a rack mount chassis, follow the following procedure:

a. Attach the rack mount adapter pieces to the instrument by first removing the four screws on the side of the instrument that attach the cover to the chassis. Attach the rack mount adapter pieces to the sides of the instrument by reinstalling the screws.

b. Install the instrument in a 19" rack by securing the front panel to the rail in each of the four corners with mounting hardware supplied by the cabinet manufacturer.

Warning

Do not remove the cabinet feet and then reinsert the original screws. Doing so could present a severe life-threatening electrical hazard. If removal of the cabinet feet is desired, replace the original screws with screws not to exceed 1/4" in length. Screws longer than 1/4" will contact and damage the printed circuit board inside the unit.

2.3 Preparing the Sensor for Connection

Prepare the sensor to be connected to the instrument by soldering the sensor leads to a male 9-pin D-Sub connector which will connect to J1 on the rear panel of the instrument. Refer to the *Appendix* of this manual and the AMI sensor manual for the proper pinout and wire color connections. Connect the sensor to connector J1 on the rear panel.

Warning

Although the sensor connector terminals are isolated from earth ground and therefore touching one terminal is not hazardous, the voltage between terminals is at a hazardous potential. The sensor connector is for use with an AMI LHe sensor and the wiring for the sensor is to have no live parts which are accessible. Conductors connected to its terminals must be insulated from user contact by basic insulation rated for 150 VAC (Category I).

The lead wire for the sensor may be sized by the following equations. For input line voltages greater than or equal to 105 VAC or 210 VAC:

$$R = 420 - 5.21L$$

For input line voltages less than 105 VAC or 210 VAC:

$$R = 337 - 5.21L$$

where *R* is the maximum allowable resistance (in ohms) for each lead wire from the instrument to the sensor, and *L* is the active length of the connected helium level sensor in inches. Please note that the maximum allowable active sensor length for input line voltages less than 105 VAC or 210 VAC is 64 inches. Tables for active sensor length vs. lead wire distance are provided below.

Minimum recommended gauge for stranded, tinned-copper lead wire for input line voltages greater than or equal to 105 VAC or 210 VAC.

<table>
<tr><th rowspan="2">Distance</th><th>*R*=367</th><th>*R*=315</th><th>*R*=263</th><th>*R*=211</th><th>*R*=107</th><th>*R*=3.2</th></tr>
<tr><th>*L*=10"</th><th>*L*=20"</th><th>*L*=30"</th><th>*L*=40"</th><th>*L*=60"</th><th>*L*=80"</th></tr>
<tr><td>10 ft.</td><td rowspan="8">36 AWG</td><td rowspan="8">36 AWG</td><td rowspan="8">36 AWG</td><td rowspan="8">36 AWG</td><td rowspan="7">36 AWG</td><td>34 AWG</td></tr>
<tr><td>20 ft.</td><td rowspan="2">30 AWG</td></tr>
<tr><td>30 ft.</td></tr>
<tr><td>40 ft.</td><td>28 AWG</td></tr>
<tr><td>50 ft.</td><td>27 AWG</td></tr>
<tr><td>100 ft.</td><td>24 AWG</td></tr>
<tr><td>200 ft.</td><td>22 AWG</td></tr>
<tr><td>500 ft.</td><td>32 AWG</td><td>16 AWG</td></tr>
</table>

Minimum recommended gauge for stranded, tinned-copper lead wire for input line voltages less than 105 VAC or 210 VAC.

<table>
<tr><th rowspan="2">Distance</th><th>*R*=284</th><th>*R*=232</th><th>*R*=180</th><th>*R*=128</th><th>*R*=24</th></tr>
<tr><th>*L*=10"</th><th>*L*=20"</th><th>*L*=30"</th><th>*L*=40"</th><th>*L*=60"</th></tr>
<tr><td>10 ft.</td><td rowspan="8">36 AWG</td><td rowspan="8">36 AWG</td><td rowspan="7">36 AWG</td><td rowspan="7">36 AWG</td><td rowspan="5">36 AWG</td></tr>
<tr><td>20 ft.</td></tr>
<tr><td>30 ft.</td></tr>
<tr><td>40 ft.</td></tr>
<tr><td>50 ft.</td></tr>
<tr><td>100 ft.</td><td>34 AWG</td></tr>
<tr><td>200 ft.</td><td>30 AWG</td></tr>
<tr><td>500 ft.</td><td>34 AWG</td><td>34 AWG</td><td>26 AWG</td></tr>
</table>

2.4 Installing the Optional Solenoid-Operated Fill Valve

Model 136 Install the solenoid-operated fill valve by connecting the valve power cable to the AC controller output receptacle on the rear panel of the instrument. The standard AMI supplied valve has a 9/32 inch orifice and the input and output are tapped for 3/8 NPT.

Caution

When using a solenoid-operated control valve with the Model 136, ensure the valve is configured for the operating voltage of the Model 136. Failure to do so will result in faulty operation and may also result in valve damage.

Warning

Before touching any of the controller output receptacle terminals or touching the wiring connected to these terminals, remove power to the instrument by unplugging it or turning the power switch to the off position.

The controller output receptacle conducts hazardous AC line voltage potentials. It is for use with equipment which has no live parts which are accessible. Conductors connected to its terminals must be insulated from user contact by reinforced or double insulation capable of withstanding 4250 V (impulse) for a 230 VAC Category II installation, or 2550 V (impulse) for a 120 VAC Category II installation.

This instrument is designed for operation from a single-phase power source for maximum safety. The controller output receptacle circuitry only switches the "line" ("hot") connection to the AC mains. If two-phase power is applied, any equipment connected to the controller output receptacle conducts hazardous AC voltage even when the controller output receptacle is not energized.

2.5 Connecting any Communications Option

If a communication option has been installed in the instrument, prepare the mating end of the connector and plug it into the communication connector on the rear panel. Refer to the applicable section of this manual for a description of the communications connector wiring.

2.6 Connecting the Instrument to Power

Warning

The Model 135/136 operates on 50-60 Hz power and may be configured for 100-120 or 200-240 VAC ±10%. The power requirements for the instrument is marked on the calibration sticker on the bottom of the instrument. Verify that your instrument is configured for your power source prior to plugging in the line cord. Do not fail to connect the input ground terminal securely to an external earth ground.

Verify that the instrument is configured for the proper operating voltage by referring to the calibration sticker affixed to the bottom of the instrument. If the operating voltage is correct, plug the line cord into the appropriate power receptacle.

Caution

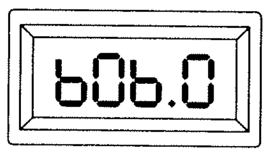
Do not install the instrument in a manner that prevents removal of the line cord from the rear panel of the instrument.

3 Operation

This section describes the front panel display and control functions for the Model 135/136. In addition to the front panel operation described, the remote communication ports provide methods for performing similar operations and querying the current state of the instrument. Refer to the Remote Interface Reference section beginning on page 21 for more details regarding the communication functions.

3.1 Sensor-Burnout Protection Mode

Operating the sensor in a vacuum without contact with liquid helium can cause thermal damage and/or destruction of the superconducting filament. The Model 135/136 is equipped with circuitry that automatically prevents this type of damage from occurring, if the instrument's LENGTH setting is properly set to the active length of the connected sensor. If excessive sensor resistance is detected, the Model 135/136 display will read:



(indicating burnout protection is in effect) and the sensor current will be turned off for a minimum of six seconds after which time the instrument will attempt to resume normal operation. No relay or alarm states are affected.

If an attached sensor is not actually installed in a cooled cryostat, then the sensor burnout protection will activate as soon as the Model 135/136 is powered-on. Please refer to the Service section for more information on checking the function of the Model 135/136 and attached helium level sensor before installation in a cryostat.

3.2 Normal Operational Mode

3.2.1 Turn on the power

Turn the POWER toggle switch to the on position. The green POWER LED located above the POWER switch will be lit. The display will show AAAA for approximately one second upon power-up during the microprocessor reset routine and then show the liquid helium level. Also during power-up, all LEDs will briefly be energized and the alarm will briefly sound as a self-test procedure.

Note

If the displayed level reading is below the LO SETPOINT level or exceeds the HI SETPOINT, an audible alarm will sound. To silence the alarm, rotate the control mode rotary switch on the front panel to the SILENCE position.

3.2.2 Configure the active length setting

Note

The Model 135/136 instrument is calibrated at the factory. No further calibration is required, however the length setting of the instrument must be matched with the active length of the sensor that is attached for proper operation.

Initially the instrument must be adjusted for the active length of the sensor. Place the units mode toggle switch in either the INCH or CM position. Place the control mode rotary switch on the front panel to the LENGTH position. To view the present length setting, push and release the RAISE/LOWER toggle switch either up or down. The display will momentarily show the present length setting. To change the length setting, use the RAISE/LOWER toggle switch to move the setting up or down by continuously holding it in the up or down position. The display will move slowly at first and then faster. Once near the desired value, simply release the switch momentarily and then resume changing the setpoint at the slower speed.

The new active sensor length is automatically permanently stored in memory. Check the value by momentarily placing the toggle switch in either position from the center position.

Note

The LENGTH adjustment can only be performed in the INCH or CM units modes. The LENGTH adjustment is inactive if the units are set for %.

3.2.3 Configure the HI SETPOINT and the LO SETPOINT

To adjust the HI and LO setpoints, place the control mode rotary switch in the HI SETPOINT position or the LO SETPOINT position, respectively. Use the RAISE/LOWER toggle switch to adjust the respective setpoint in the same manner as described for the LENGTH adjustment in paragraph 3.2.2. The setpoints may be located anywhere between 0% to 100% of the active sensor length. The HI and LO setpoint adjustments are compatible with all three units modes.

a. When the measured liquid level exceeds the HI setpoint, the HI LEVEL LED on the front panel is energized and a set of relay contacts are closed on the 9-pin D connector J2 on the rear panel (see the *Appendix* for the pinout). When the level reaches or falls below the HI setpoint, the LED is extinguished and the relay contacts open.

b. When the measured liquid level falls below the LO setpoint, the LO LEVEL LED on the front panel is energized and a set of relay contacts are closed on the 9-pin D connector J2 on the rear panel (see the *Appendix* for the pinout). When the level reaches or exceeds the LO setpoint, the LED is extinguished and the contacts open.

Note

The HI and LO contacts are both closed on power-off of the instrument which is a state unique to the power-off condition.

Note

If the LENGTH is adjusted subsequent to configuring the various setpoints, the percentage of active length will be maintained for all setpoints. For example, if the LENGTH is set to 100 cm and the HI SETPOINT is set to 80 cm, then adjusting the LENGTH to 150 cm will result in the HI SETPOINT being automatically scaled to 120 cm—i.e. the setting of 80% of active length is maintained.

3.2.4 Configure the A SETPOINT and the B SETPOINT

Model 136

To adjust the A and B setpoints which specify the upper and lower limits for the liquid level control band, place the control mode rotary switch in the A SETPOINT position or the B SETPOINT position, respectively. Use the RAISE/LOWER toggle switch to adjust the respective setpoint in the same manner as described for the LENGTH adjustment in paragraph 3.2.2. The A and B setpoint adjustments are compatible with all three units modes.

a. When the measured liquid level reaches or exceeds the A setpoint, the A LEVEL LED on the front panel is energized. When the level falls below the A setpoint, the LED is extinguished.

b. When the measured liquid level falls below the B setpoint, the B LEVEL LED on the front panel is energized. When the level reaches or exceeds the B setpoint, the LED is extinguished.

c. In addition to the LED functions, the controller output receptacle may be energized and de-energized as discussed in step 5 below.

Note

The A setpoint must always be above the B setpoint. The firmware does not allow these setpoints to be reversed. Both setpoints may be set from 0% to 100% of the LENGTH setting as long as A > B.

3.2.5 Select the operational mode of the controller output receptacle

Model 136 The operation of the CONTROLLER OUTPUT receptacle of the instrument is controlled by the fill toggle switch. Operation of the fill toggle switch is as follows:

a. **CLOSED** (or **OFF**): With the power on and the fill switch in the CLOSED position, the instrument serves only as a level monitor, giving a level reading on the digital display and providing data via any analog or communication options installed. All four setpoint LEDs (and associated J2 connector relay contacts) operate normally, however, the controller output receptacle on the rear panel will *always* be de-energized.

b. **OPEN** (or **ON**): With the fill switch in the OPEN position, the rear panel CONTROLLER OUTPUT receptacle will become energized, thereby initiating flow if the solenoid-operated fill valve is properly connected. The FILL LED on the front panel will light indicating the presence of power at the controller output receptacle. **The operator is solely responsible for terminating the fill flow.**

c. **AUTO:** With the fill switch in the AUTO position, the instrument is capable of automatically initiating and terminating liquid fill via the control valve, thereby maintaining the level between the selected A and B setpoints. If the liquid level falls below the B setpoint, the rear panel CONTROLLER OUTPUT receptacle and front panel FILL LED are energized. When the liquid level subsequently reaches or exceeds the A setpoint, the controller output receptacle is de-energized and the FILL LED is extinguished.

Note

The Model 136 has precautionary measures programmed for cases where the sensor may be accidently disconnected. If the sensor is disconnected, the level reading will be 100% after the next measurement, which effectively de-energizes the controller output if operating in the AUTO mode.

3.2.6 Configure the sample time interval setting

To adjust the sample time interval, place the control mode rotary switch in the INTERVAL position. Use the RAISE/LOWER toggle switch to adjust the time interval in the same manner as described in paragraph 3.2.2. The instrument is shipped with the time interval set for 1.0 minutes. This value can be changed to any setting between 0 and 600 minutes.

Warning

Before removing the cover of the instrument, remove power from the instrument by disconnecting the power cord from the power receptacle. Failure to do this could expose the user to high voltages and could result in life-threatening electrical shock.

If desired, the sample interval can be changed to hours. To accomplish this, the unit must be de-energized and the cover removed so that jumper W1 (located on the printed circuit board vertically mounted directly behind the front panel) can be moved from MIN to HR position. The jumper position can be determined from the front panel at any time. When the jumper is in the hour position, the display will briefly flash 'hhh.h' when the RAISE/LOWER switch is moved out of the center position (with the control mode rotary switch in the INTERVAL position) and then will display the time to tenths of an hour. When the jumper is in the minute position, the display does not flash 'hhh.h'.

3.2.7 Select either continuous or sampled update configuration

Place the sampling mode toggle switch in the UPDATE position for continuous level readings, or in the SAMPLE position for readings taken at time intervals according the INTERVAL setting. All sample time intervals are initialized from the time the instrument was last powered on.

If the sampling mode toggle switch is the UPDATE position, the resistive zone of the sensor is kept in continuous contact with the surface of the liquid helium. This results in heating effects and an accelerated loss of liquid helium. The SAMPLE position allows the unit to perform a measurement and then de-energize the sensor, thereby minimizing the heating effects and loss of liquid helium.

3.2.8 Select the appropriate units display option

Place the units mode toggle switch in the position desired for the display output units. The % position displays the percentage of active sensor length that is immersed in liquid helium.

3.2.9 Connect the optional analog output signal

If the instrument was purchased with an analog output option, the auxiliary connector J2 on the rear of the instrument provides a 0-10 VDC or 4-20 mA analog signal corresponding to 0-100% of liquid level. Refer to the *Appendix* for the pinout diagram of connector J2.

3.3 Dirty Sensor Operational Mode

AMI expects the helium level sensor to be reasonably clean and free from oil, water, ice, etc. for proper operation. However, it is recognized that some experiments might result in some material being deposited on the sensor wire. Ice formation at some point on the sensor is a typical occurrence. Therefore, the Model 135/136 has the capability of increasing the current for a short period of time at the beginning of the measurement cycle (in the SAMPLE mode only) to try and drive the resistive zone of the sensor wire past the dirty region. This operation may or may not be successful depending on the degree of sensor contamination. This mode should be viewed as a stopgap measure only. If correct readings cannot be reestablished, the only choice is to warm the sensor or remove for cleaning or replacement.

Note

Operation in the dirty sensor mode increases liquid helium losses. Consequently, operation in this mode should not be used unless the sensor is known or anticipated to become dirty or the helium level measurement is in question due to unclean operation.

The procedure for configuring the Model 135/136 for the dirty sensor operational mode is documented on page 52 in the Service section of this manual.

4 Remote Interface Reference

4.1 Serial Communication/Data Logger Option

The serial communication/data logger option provides a 25-pin D-type connector on the rear panel of the instrument for serial communications and data logger function.

4.1.1 Serial port connector and cabling

An IBM-compatible computer's serial port can be directly connected to the Model 135/136 via a standard PC modem cable. Refer to your computer's documentation to determine which serial ports are available on your computer and the required connector type. The cable to connect two DB25 connectors is wired directly, i.e. pin 1 to pin 1, pin 2 to pin 2, etc. If a DB9 connector is required at the computer interface, the connector translation is provided in the Appendix.

The Model 135/136 uses only three wires of the rear-panel DB25 connector: pin 2 (receive), pin 3 (transmit), and pin 7 (common). There is no software or hardware handshaking. The Model 135/136 is classified as a DCE (Data Communication Equipment) device since it transmits data on pin 3 and receives data on pin 2. The instrument to which the Model 135/136 is attached must do the opposite, i.e., transmit on pin 2 and receive on pin 3 (the requirements for a DTE, or Data Terminal Equipment device). If a serial-to-parallel converter is used, it must be capable of receiving data on pin 3 or the cable connected to the Model 135/136 must interchange the wires between pins 2 and 3.

Optional RS-422 connector pinout is provided on page 58.

4.1.2 Command/return termination characters

All commands are transmitted and received as ASCII values and are case insensitive. The Model 135/136 always transmits *<CR><LF>* (i.e. a *carriage return* followed by a *linefeed*) at the end of an RS-232 transmission. The Model 135/136 can accept *<CR>*, *<LF>*, *<CR><LF>*, or *<LF><CR>* as termination characters from an external computer.

The simplest method for communicating with the Model 135/136 via RS-232 is by using the interactive mode of a commercially available terminal emulation program. The Model 135/136 transmits and receives information at various baud rates and uses 8 data bits, no parity, and 1 stop bit. When the Model 135/136 receives a terminated ASCII string, it always sends back a reply as soon as the string is processed. *When sending commands to the Model 135/136, you must wait for the reply from the Model 135/136 before sending another command even if the reply consists* *of only termination characters.* Otherwise, the shared input/output command buffer of the Model 135/136 may become corrupted. No other form of flow control is supported.

4.1.3 Serial Communication DIP Switch Settings

The 8 DIP switches located on the rear panel of the Model 135/136 are used to control various parameters of the serial interface. Switches 6 through 8 control the baud rate of the interface. Switches 3 through 5 are unused. Switch 2 controls the echo feature and switch 1 controls the data logger function. Each of these features is fully discussed below.

4.1.3.1 Baud rate control

The Model 135/136 baud rate is controlled by switches 6 through 8 of the communication DIP switch on the rear panel. The unit is shipped with the baud rate set at 9600. The switch settings for various baud rates are (on = 1 or the up position):

DIP switch			Baud rate
6	7	8	
off	off	off	300
off	off	on	600
off	on	off	1200
off	on	on	2400
on	off	off	4800
on	off	on	9600

4.1.3.2 Echo function

The Model 135/136 has an *echo* feature which is enabled or disabled by communication DIP switch 2. When the echo function is enabled, the Model 135/136 will echo the incoming command characters back to the transmitting device. The echo feature is useful when using an interactive terminal program on a host computer for communicating with the Model 135/136 (however, most terminal programs support a local echo feature). The settings are:

DIP switch 2	Function
on	Echo On
off	Echo Off

4.1.3.3 Data logger function

Switch 1 of the communications DIP switch controls the data logger function. This feature is normally used with a printer rather than a host computer, since a computer can be more usefully programmed utilizing the available command set. The data logger function generates a time relative to instrument power-up and a corresponding helium level. The time and corresponding helium level are formatted and output to the host device at regular intervals as specified by the INTERVAL setting (the INTERVAL setting may be set via the front panel, see page 3). The host device can be a standard dot matrix printer connected via a serial-to-parallel converter, or directly with a printer capable of receiving serial data. Presumably, any serial-to-parallel converter which can be properly configured is acceptable. AMI has tested the Model 135/136 with a standard, low cost converter configured as a DTE device, 8 data bits, no parity, and 1 stop bit. In order to communicate with the host device, it is necessary to set the Model 135/136 to the identical baud rate of the host device. The settings for the data logger function are:

DIP switch 1	Function
on	Data Logger On
off	Data Logger Off

4.1.4 Serial Command Set Reference

All commands sent to the Model 135/136 are processed and the Model 135/136 responds with the answer. If the command is invalid, the Model 135/136 will respond with *-8*. All return values are terminated with *<CR><LF>* (i.e. a *carriage return* followed by a *linefeed*). For those commands that do not return a value, the Model 135/136 will return the *<CR><LF>* termination only.

4.1.4.1 Commands for controlling the units of measurement

Command:	CM	**Function:**	Sets the units of measurement to centimeters	**Returns:**	<CR> <LF>
Command:	INCH	**Function:**	Sets the units of measurement to inches	**Returns:**	<CR> <LF>
Command:	PERCENT	**Function:**	Sets the units of measurement to % of sensor length	**Returns:**	<CR> <LF>
Command:	UNIT	**Function:**	Returns the current units in use	**Returns:**	C, I, or % <CR> <LF>

The CM command sets the units of measurement to centimeters and the INCH command selects inches. The PERCENT command sets the units of measurement to the percentage of active sensor length that is immersed in liquid helium. **The units of measurement selected through the serial interface are controlled independently from the units mode toggle switch used for controlling the front panel display.** The remote units setting is saved in permanent memory by the SAVE command and is restored at power-up. The UNIT command returns a one character value (and termination) indicating the current units—C for centimeters, I for inches, or % for percentage.

4.1.4.2 Commands for configuring permanent memory

	Command:	LENGTH=*<value>*	**Function:**	Configures the active sensor length	**Returns:**	<CR> <LF>
	Command:	HI=*<value>*	**Function:**	Configures the HI setpoint limit	**Returns:**	<CR> <LF>
	Command:	LO=*<value>*	**Function:**	Configures the LO setpoint limit	**Returns:**	<CR> <LF>
Model 136	**Command:**	A=*<value>*	**Function:**	Configures the A setpoint (control band upper limit)	**Returns:**	<CR> <LF>
Model 136	**Command:**	B=*<value>*	**Function:**	Configures the B setpoint (control band lower limit)	**Returns:**	<CR> <LF>
	Command:	INTERVAL= *<value>*	**Function:**	Configures the sampling interval	**Returns:**	<CR> <LF>
	Command:	SAVE	**Function:**	Saves the configuration to permanent memory	**Returns:**	<CR> <LF>

The LENGTH command configures the active sensor length setting in the current units. LENGTH=35.0 would configure the active sensor length to 35.0 units of centimeters or inches.

Note

The LENGTH=<value> command will only function if CM or INCH are currently selected as the units of measurement. The LENGTH command does not configure the Model 135/136 if the units of measurement are PERCENT.

The HI and LO commands configure the high and low setpoint limit values respectively. For example, HI=90.0 would configure the high setpoint limit to 90.0 in whichever units of measurement last selected through the serial interface. The A and B commands configure the upper limit and lower limit of the control band, respectively. The HI, LO, A, and B commands are compatible with the percent units selection.

The INTERVAL command sets the sampling interval used if the instrument is set for sampling mode operation (as opposed to continuous update) via the sampling mode toggle switch. INTERVAL=0.1 would set the sampling interval to 0.1 minutes (or 0.1 hours if so configured, see page 53). The SAVE command saves the HI, LO, A, B, INTERVAL, LENGTH, and current remote units settings to permanent memory. These settings are then recalled each time the power is turned off and then reapplied to the instrument. If the configuration is changed from the front panel, the settings are automatically saved to permanent memory.

4.1.4.3 Commands for querying the configuration

	Command:	LENGTH	**Function:**	Returns the active sensor length in the current units	**Returns:**	<value> <CR> <LF>
	Command:	HI	**Function:**	Returns the HI setpoint limit in the current units	**Returns:**	<value> <CR> <LF>
	Command:	LO	**Function:**	Returns the LO setpoint limit in the current units	**Returns:**	<value> <CR> <LF>
Model 136	**Command:**	A	**Function:**	Returns the A setpoint limit in the current units	**Returns:**	<value> <CR> <LF>
Model 136	**Command:**	B	**Function:**	Returns the B setpoint limit in the current units	**Returns:**	<value> <CR> <LF>
	Command:	INTERVAL	**Function:**	Returns the sampling interval in the current units	**Returns:**	<value> <CR> <LF>

The LENGTH, HI, LO, A, B, and INTERVAL commands return the current configuration of the instrument. Each return value is terminated with *<CR><LF>*.

4.1.4.4 Commands for performing level measurements

Command:	LEVEL	**Function:**	Returns the liquid helium level in the current units	**Returns:**	<value> <CR> <LF>
Command:	HOLD	**Function:**	Immediately ceases level measurements	**Returns:**	<CR> <LF>
Command:	MEASURE	**Function:**	Initiates level measurement in the current sampling mode	**Returns:**	<CR> <LF>

The LEVEL command returns the liquid helium level in the current units selected. If a measurement is in progress when the instrument is queried for the LEVEL, then the LEVEL command (and in fact, all commands) will not return a value until the measurement is complete. The time required to complete a level measurement is variable and depends upon the active length of the sensor and the sampling mode. Measurement times normally range from several milliseconds to 15 seconds. Sampling in the UPDATE mode usually returns immediately since the resistive zone of the sensor is kept in continuous contact with the surface of the liquid helium. The return value (and termination characters) from the LEVEL command *must be received before sending another command to the Model 135/136.*

The HOLD command ceases level measurements regardless of the sampling mode selected. A new measurement will not be initiated until the MEASURE command is subsequently received. The MEASURE command resumes level measurement in the sampling mode as selected by the sampling mode toggle switch on the front panel.

Note

The MEASURE command resumes measurement of the liquid helium level in the mode determined by the sampling mode toggle switch on the front panel. If the sampling mode toggle switch is in the UPDATE position, the sensor current will turn on and the instrument will continually update. If the switch is in the SAMPLE position, the sensor current will briefly turn on to allow the instrument to perform an immediate measurement, then turn off. The instrument will then remain in the SAMPLE mode with the interval and start time of the sampling function undisturbed.

4.2 IEEE-488 Communication Option

The IEEE-488 communication option provides a GPIB connector on the rear panel of the instrument for IEEE-488 (GPIB, HPIB) communications.

4.2.1 Command/return termination characters

All commands are transmitted and received as ASCII values and are case insensitive. The Model 135/136 always transmits <LF> and EOI as the termination for return data. The Model 135/136 can accept <CR>, <LF>, <CR><LF>, <LF><CR>, or <LF> with EIO as termination characters from an external IEEE-488 interface.

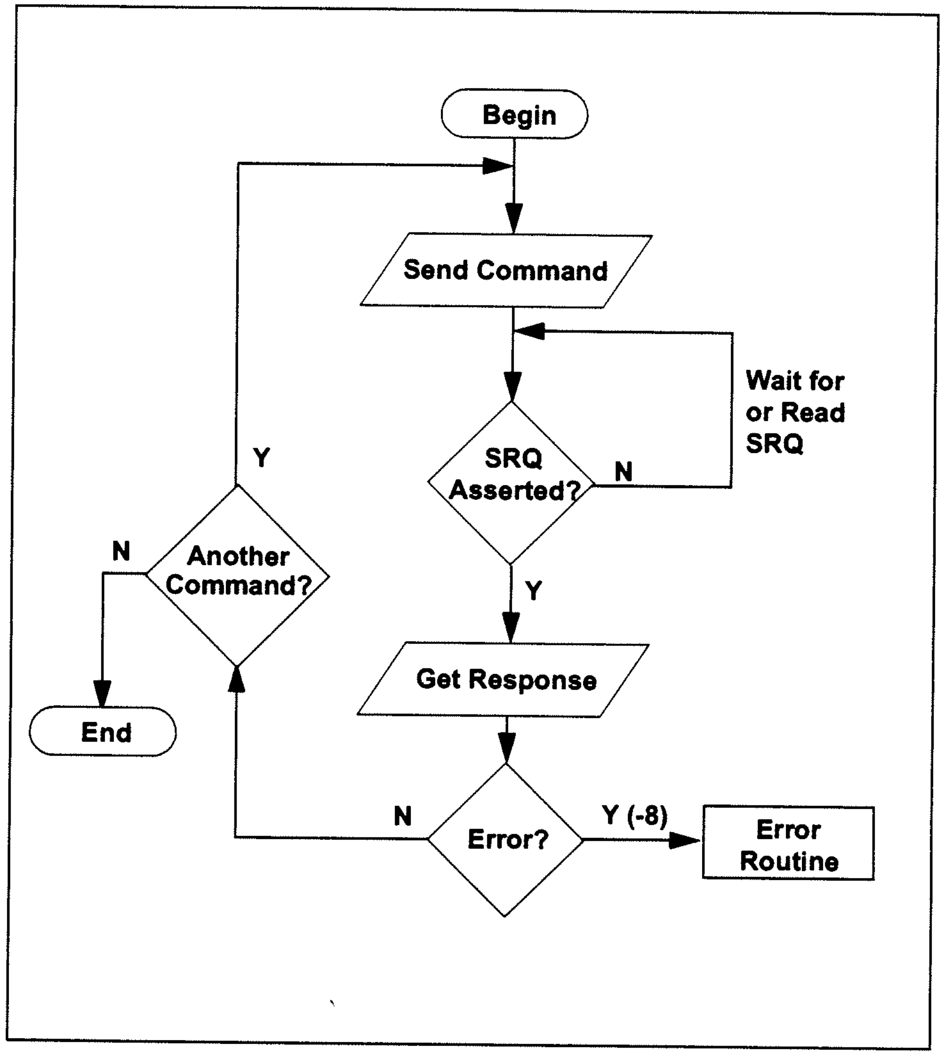
Only one command at a time is allowed to be transmitted by the external IEEE-488 interface. Thus the transmission of several commands separated by a semicolon is not allowed. The instrument uses a single 16 character buffer for input and output. Consequently, all input strings including terminations should not be longer than 16 characters. Any excess characters will be discarded. All alphabetical characters are case insensitive and character encoding is in accordance with IEEE 488.2.

4.2.2 Communicating with the Model 135/136

The use of a single buffer for both input and output is a result of memory limitations in the Model 135/136. In order to keep the external IEEE-488 interface from sending successive commands faster than the Model 135/136 can respond, the Model 135/136 uses the Serial Poll Service Request (SRQ) to let the external computer know it has finished processing the last command received and is ready to send a response. This is true of all commands. Thus sending commands to the Model 135/136 using IEEE-488 protocol is a three step process: 1) send the ASCII command, 2) wait for SRQ, and 3) get the instrument response.

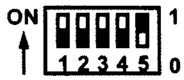
> **Note**
>
> *API's for some manufacturer's cards require you to use different functions to check for SRQ and read the serial poll status (spoll) byte. Invoking the command to read the spoll byte may be required to actually clear the SRQ status.*

A basic flow diagram for sending an ASCII command to the Model 135/136 and receiving a response is shown on the following page. It is not necessary to wait exclusively for the SRQ status from the instrument. Other bus commands can be processed while waiting for the SRQ status from the instrument.



Basic communication flow diagram for IEEE-488 commands.

4.2.3 IEEE-488 Communication DIP Switch Settings



The 5 DIP switches located on the rear panel of the Model 135/136 are used to control the IEEE-488 interface. Switches 1 through 5 control the IEEE-488 bus address of the unit.

4.2.3.1 IEEE-488 primary bus address

The Model 135/136 primary bus address is controlled by switches 1 through 5 of the communication DIP switch on the rear panel. Valid primary addresses are between 0 and 30. The Model 135/136 does not use secondary addressing. Note that many IEEE-488 controller cards in external computers will use address 0. The bus address for each Model 135/136 *should be unique* with respect to other Model 135/136 units or any other devices on the bus. The switch settings for the various addresses are (on = 1 or the up position):

DIP switch					Primary bus address
1	2	3	4	5	
off	off	off	off	off	0
off	off	off	off	on	1
off	off	off	on	off	2
off	off	off	on	on	3
off	off	on	off	off	4
off	off	on	off	on	5
off	off	on	on	off	6
off	off	on	on	on	7
off	on	off	off	off	8
off	on	off	off	on	9
off	on	off	on	off	10
off	on	off	on	on	11
off	on	on	off	off	12
off	on	on	off	on	13
off	on	on	on	off	14
off	on	on	on	on	15
on	off	off	off	off	16
on	off	off	off	on	17

DIP switch					Primary bus address
1	2	3	4	5	
on	off	off	on	off	18
on	off	off	on	on	19
on	off	on	off	off	20
on	off	on	off	on	21
on	off	on	on	off	22
on	off	on	on	on	23
on	on	off	off	off	24
on	on	off	off	on	25
on	on	off	on	off	26
on	on	off	on	on	27
on	on	on	off	off	28
on	on	on	off	on	29
on	on	on	on	off	30

4.2.4 IEEE-488 Command Set Reference

All commands sent to the Model 135/136 are processed and the Model 135/136 responds with the answer. If the command is invalid, the Model 135/136 will respond with *-8*. All return values are terminated with *<LF>* (*linefeed*) and EOI asserted. For those commands that do not return a value, the Model 135/136 will echo the command string in the return message. The Model 135/136 does not implement a full complement of IEEE 488.2 commands, nor does it conform to the Standard Commands for Programmable Instruments (SCPI) protocol. These limitations are due to memory constraints in the microprocessor (subject to change in the future).

4.2.4.1 Device clear (DCL) command

The Model 135/136 responds to the device clear (DCL) command from a host IEEE controller. The device clear resets the instrument. The default units are centimeters and the permanently saved configuration settings are restored.

4.2.4.2 Commands for controlling the units of measurement

Command:	CM	Function:	Sets the units of measurement to centimeters	Returns:	CM
Command:	INCH	Function:	Sets the units of measurement to inches	Returns:	INCH
Command:	PERCENT	Function:	Sets the measurement to % of active sensor length	Returns:	%
Command:	UNIT	Function:	Returns the current units in use	Returns:	C, I, or %

The CM command sets the units of measurement to centimeters and the INCH command selects inches. The PERCENT command sets the units of measurement to the percentage of the active sensor length that is immersed in liquid helium. **The units of measurement selected through the IEEE-488 interface are controlled independently from the units mode toggle switch used for controlling the front panel display.** The remote units setting is saved in permanent memory by the SAVE command and is restored at power-up. The UNIT command returns a one character value (and termination) indicating the current units—C for centimeters, I for inches, or % for percentage.

4.2.4.3 Commands for configuring permanent memory

	Command:		Function:		Returns:	
	Command:	LENGTH= *<value>*	**Function:**	Configures the active sensor length	**Returns:**	LENGTH= *<value>*
	Command:	HI=*<value>*	**Function:**	Configures the HI setpoint limit	**Returns:**	HI=*<value>*
	Command:	LO=*<value>*	**Function:**	Configures the LO setpoint limit	**Returns:**	LO=*<value>*
Model 136	**Command:**	A=*<value>*	**Function:**	Configures the A setpoint (control band upper limit)	**Returns:**	HI=*<value>*
Model 136	**Command:**	B=*<value>*	**Function:**	Configures the B setpoint (control band lower limit)	**Returns:**	LO=*<value>*
	Command:	INTERVAL= *<value>*	**Function:**	Configures the sampling interval	**Returns:**	INTERVAL= *<value>*
	Command:	SAVE	**Function:**	Saves the configuration to permanent memory	**Returns:**	SAVE

The LENGTH command configures the active sensor length setting in the current units. LENGTH=35.0 would configure the active sensor length to 35.0 units of centimeters or inches.

Note

The LENGTH=<value> command will only function if CM or INCH are currently selected as the units of measurement. The LENGTH command does not configure the Model 135/136 if the units of measurement are PERCENT.

The HI and LO command configure the high and low setpoint limit values respectively. For example, HI=90.0 would configure the high setpoint limit to 90.0 in whichever units of measurement last selected through the IEEE-488 interface. The A and B commands configure the upper limit and lower limit of the control band, respectively. The HI, LO, A, and B commands are compatible with the percent units selection.

The INTERVAL command sets the sampling interval used if the instrument is set for sampling mode operation (as opposed to continuous update) via the sampling mode toggle switch. INTERVAL=0.1 would set the sampling interval to 0.1 minutes (or 0.1 hours if so configured, see page 53). The SAVE command saves the HI, LO, A, B, INTERVAL, LENGTH, and current remote units settings to permanent memory. These settings are then recalled each time the power is turned off and then reapplied to the instrument. If the configuration is changed from the front panel, the settings are automatically saved to permanent memory.

4.2.4.4 Commands for querying the configuration

	Command:	LENGTH	**Function:**	Returns the sensor length in the current units	**Returns:**	<value>
	Command:	HI	**Function:**	Returns the HI setpoint limit in the current units	**Returns:**	<value>
	Command:	LO	**Function:**	Returns the LO setpoint limit in the current units	**Returns:**	<value>
Model 136	**Command:**	A	**Function:**	Returns the A setpoint limit in the current units	**Returns:**	<value>
Model 136	**Command:**	B	**Function:**	Returns the B setpoint limit in the current units	**Returns:**	<value>
	Command:	INTERVAL	**Function:**	Returns the sampling interval in the current units	**Returns:**	<value>

The LENGTH, HI, LO, A, B, and INTERVAL commands return the current configuration of the instrument. Each return value is terminated with *<LF>* and EOI.

4.2.4.5 Commands for performing level measurements

Command:	LEVEL	**Function:**	Returns the liquid helium level in the current units	**Returns:**	<value>

Command:	HOLD	**Function:**	Immediately ceases level measurements	**Returns:**	HOLD

Command:	MEASURE	**Function:**	Initiates level measurement in the current sampling mode	**Returns:**	MEASURE

The LEVEL command returns the liquid helium level in the current units selected. If a measurement is in progress when the instrument is queried for the LEVEL, then the LEVEL command (and in fact, all commands) will not return a value until the measurement is complete. The time required to complete a level measurement is variable and depends upon the active length of the sensor and the sampling mode. Measurement times normally range from several milliseconds to 15 seconds. Sampling in the UPDATE mode usually returns immediately since the resistive zone of the sensor is kept in continuous contact with the surface of the liquid helium. The return value (and termination characters) from the LEVEL command *must be received before sending another command to the Model 135/136.*

The HOLD command ceases level measurements regardless of the sampling mode selected. A new measurement will not be initiated until the MEASURE command is subsequently received. The MEASURE command resumes level measurement in the sampling mode as set by the sampling mode toggle switch on the front panel.

Note

The MEASURE command resumes measurement of the liquid helium level in the mode determined by the sampling mode toggle switch on the front panel. If the sampling mode toggle switch is in the UPDATE position, the sensor current will turn on and the instrument will continually update. If the switch is in the SAMPLE position, the sensor current will briefly turn on to allow the instrument to perform and immediate measurement, then turn off. The instrument will then remain in the SAMPLE mode with the interval and start time of the sampling function undisturbed.

4.2.5 Serial Poll Status Byte

The IEEE-488 serial poll status byte (spoll byte) can be used to obtain information about the state of the instrument. Bit 7 of the status byte is reserved for SRQ. The remaining bits are used to provide custom information as shown in the table below.

	Bit	ON	OFF
	1 (LSB)	HI relay on	HI relay off
Model 136	2	A relay on	A relay off
Model 136	3	B relay on	B relay off
	4	LO relay on	LO relay off
Model 136	5	Fill mode on (controller output energized)	Fill mode off (controller output de-energized)
	6	Data ready for this unit	No data available
	7	Service Request (SRQ)	No SRQ
	8	Not used	Not used

Note

The fill mode indication is only accurate if the fill toggle switch on the front panel is in the AUTO position. There is no remote indication or control available for the OPEN or CLOSED manual override selections.

4.3 Error Codes

The Model 135/136 returns specific error codes for invalid commands and/ or arguments. If an error condition is returned, the command is not processed and the configuration of the instrument is *not* modified. The table below provides a list of error codes, their meaning, and any associated limits. The error codes are common to both the serial and IEEE-488 communication options.

	Error Code	Meaning	Valid Range
	−1	LO setpoint out of range	0 ≤ LO ≤ LENGTH
Model 136	−2	B setpoint out of range	0 ≤ B < A
Model 136	−3	A setpoint out of range	B < A ≤ LENGTH
	−4	HI setpoint out of range	0 ≤ HI ≤ LENGTH
	−5	Attempted to set or query for LENGTH in PERCENT units mode	
	−6	Invalid argument, *value* out of maximum calibration range	1 cm ≤ *value* ≤ 203.2 cm
	−7	INTERVAL setting out of range	0 ≤ INTERVAL≤ 600 min
	−8	Unrecognized command	
	−9	Invalid argument, value was negative or non-numeric	

5 Virtual Instrument Operation

In order to make the communications options easier to use for the customer, AMI provides a LabVIEW®-based interface for remote monitoring and control of the Model 135/136. LabVIEW is a virtual instrument (VI) development and deployment software tool produced and marketed by National Instruments. LabVIEW is available on several platforms including Microsoft Windows™, Microsoft Windows NT™, Apple Macintosh™, Sun Solaris™, and HP-UX™. The AMI provided VI's are developed and tested under Microsoft Windows 3.1 and 3.11, however, they should be portable with only minor modifications across all LabVIEW-supported platforms. Please contact National Instruments for detailed information on the available products and specifications.

The AMI provided VI's are supplied on one 3.5" 1.44 MB diskette. ***The VI's require version 3.1 (or above) of LabVIEW and a minimum of a 256 color display.*** The VI's are stored in one LabVIEW VI Library (LLB) file which contains the multiple VI's needed for operation of the instrument as a whole. AMI's provided VI's are designed for continuous operation under the control of LabVIEW, and do not conform to the instrument driver specifications to which National Instruments' own instrument drivers adhere. Any additional functionality gained by conforming to such specifications was deemed of minimal value by AMI due to the relative simplicity of communicating with the Model 135/136 instrument.

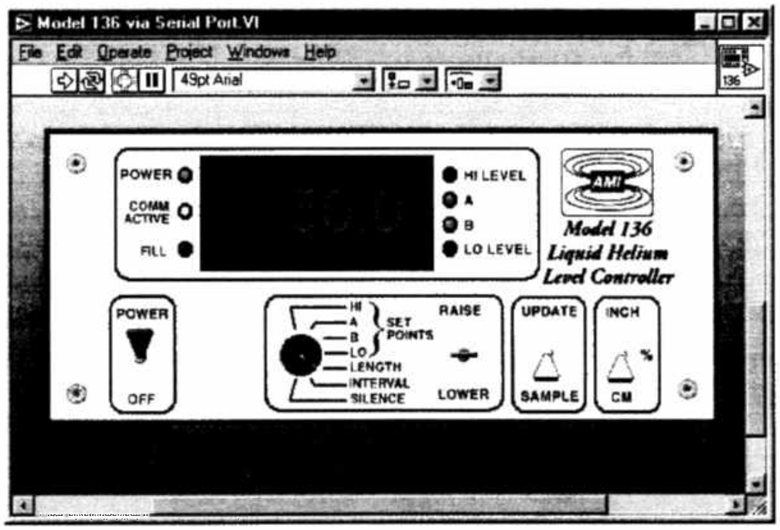
Note

Virtual instrument names which are common to both the Model 135 and Model 136 drivers are noted as "13X" in this section. The actual model number "135" or "136" is used in the LabVIEW VI's.

5.1 RS-232 Virtual Instrument

The figure below illustrates the front panel of the Model 136 virtual instrument (VI). The front panel appears nearly identical to the front panel of the actual instrument. The Model 135 virtual instrument is similar in appearance. The functionality of the VI's is very similar to that of the actual instruments as well.

When running the VI it is important to operate the instrument using the VI and not via the actual instrument front panel. Otherwise, the VI and the actual instrument may not be synchronized. The only exceptions to this rule are operation of the sampling mode toggle switch or operation of the relay control rotary switch if manual override becomes necessary. The sampling mode toggle switch should be set via the



front panel of the actual instrument to the mode desired by the operator. The VI's representation of the sampling mode toggle switch overrides any actual front panel setting by forcing the actual instrument to perform an immediate measurement when placed in the UPDATE position.

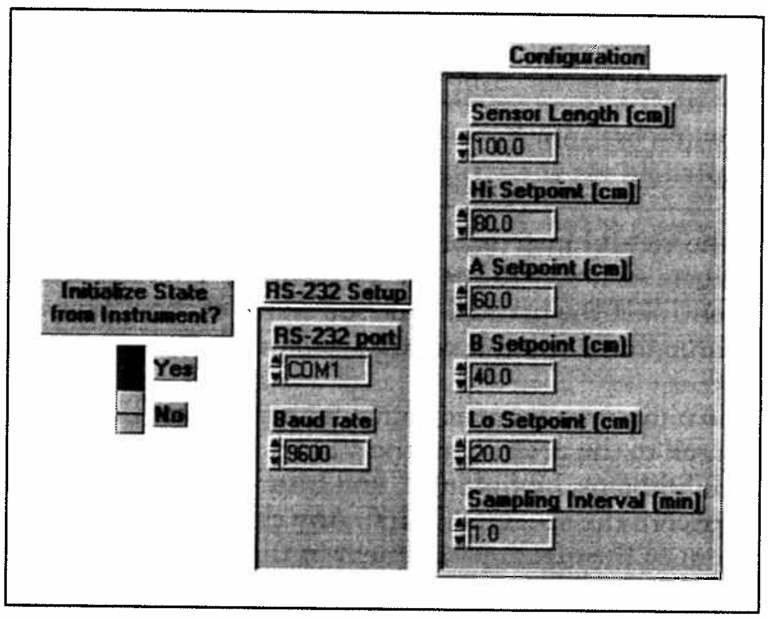
5.1.1 Launching and initializing the RS-232 VI

First, make sure the Model 135/136 is connected to a COM port on the host computer and that the instrument is powered on. The VI library, provided in the file MODEL13X.LLB, for the RS-232 virtual instrument contains the following files:

VI	Function
13X Alarms.vi	Manages alarm functions for 135/136.
Config 13X via Serial Port.vi	Initializes actual instrument from VI configuration.
Convert from CM.vi	Displays inches or percentage given input in cm.
Counter.vi	Timer function for the virtual display.
Get 13X Level via Serial Port.vi	Updates virtual display with current level.
Init from 13X via Serial Port.vi	Initializes VI configuration from actual instrument.
Model 13X via Serial Port.vi	The main VI containing the configuration and front panel controls. This is the VI the user should open and execute.

	VI	Function
	Serial Port Send.vi	Manages sending and receiving of ASCII strings from the actual instrument.
Model 136	Set 136 A via Serial Port.vi	Configures the A setpoint.
Model 136	Set 136 B via Serial Port.vi	Configures the B setpoint.
	Set 13X Interval via Serial Port.vi	Configures the sampling interval setting.
	Set 13X HI via Serial Port.vi	Configures the HI setpoint.
	Set 13X Length via Serial Port.vi	Configures the sensor length.
	Set 13X LO via Serial Port.vi	Configures the LO setpoint.

Open the *Model 13X via Serial Port.vi.* Before running the VI, the user must select an initialization option and provide any necessary settings. In order to initialize the VI, scroll to the area above the virtual front panel. Several controls are visible for setup by the user. The figure below illustrates the available controls. The *Initialize State from Instrument?* switch allows the user to select whether the instrument is initialized from the current settings of the actual instrument or from the controls available from the VI. If the *Yes* option is selected, the VI will initialize all settings



from the actual instrument. If the *No* option is selected, the user should enter all data in the control fields (*Sensor Length, Hi Setpoint,* etc.) in the indicated units.The user should also select the correct RS-232 port and baud rate, according to the port to which the Model 135/136 is connected and the baud rate to which the Model 135/136 is set (see page 22 for instructions on setting the baud rate). The user may then start the VI. Please refer to your LabVIEW documentation for instructions on how to start and control the execution of VI's.

5.1.2 Interacting with the running VI

While the VI is running the user may manipulate the virtual toggle and rotary switches in the same manner as required for the front panel operation of the actual instrument. See the Operation section of this manual for instructions on operating the front panel controls, however, please note that there are some minor differences discussed below.

The RAISE/LOWER toggle switch functions slightly different in the VI. If the RAISE/LOWER toggle switch is moved from the center position to the RAISE or LOWER position, then the display changes to show the appropriate parameter. After approximately 4 seconds in the RAISE or LOWER position, the display will begin incrementing or decrementing by tenths. After approximately 12 additional seconds, the display will begin incrementing/decrementing by ones. Move the RAISE/LOWER toggle switch back to the center position to stop the incrementing or decrementing function.

As previously discussed, *only the sampling mode toggle switch or fill toggle switch should be manipulated via the front panel of the actual instrument while the VI is running.* The VI representation of the sampling mode toggle switch forces the actual instrument to perform an immediate measurement when placed in the UPDATE position. When placing the VI switch in the UPDATE position, it must be left in the UPDATE position for at least a couple of seconds in order to be recognized. Simply place the switch back in the SAMPLE position to return to the operational mode specified via the actual instrument's sampling mode toggle switch.

The virtual instrument's FILL LED indicator is only accurate if the fill toggle switch is in the AUTO position. There is no remote monitoring or control of the manual override states of the fill toggle switch available through the communication command set.

As a more convenient option for controlling the settings, the user may scroll to the area above the VI and enter the values for the Sensor Length, Hi Setpoint, Lo Setpoint, and Interval directly in the control fields (please observe the specified units). Any changes in the fields are recognized and sent to the actual instrument in the form of the appropriate command string. Any settings changed by the VI virtual panel toggle switches or control fields are saved in permanent memory in the actual instrument.

The VI may be gracefully stopped by using the STOP toggle switch in the lower left corner of the VI. After stopping the VI, this switch must be placed back in the up position in order to restart the VI.

5.2 IEEE-488 Virtual Instrument

The IEEE-488 (or GPIB) VI functions nearly identically to the RS-232 VI with a few exceptions. The VI library, provided in the file MODEL13X.LLB, for the IEEE-488 virtual instrument contains the following files:

	VI	Function
	13X Alarms.vi	Manages alarm functions for 135/136.
	Config 13X via GPIB.vi	Initializes actual instrument from VI configuration.
	Convert from CM.vi	Displays inches or percentage given input in cm.
	Counter.vi	Timer function for the virtual display.
	Get 13X Level via GPIB.vi	Updates virtual display with current level.
	Init from 13X via GPIB.vi	Initializes VI configuration from actual instrument.
	Model 13X via GPIB.vi	The main VI containing the configuration and front panel controls. This is the VI the user should open and execute.
	Non-exclusive loop control.vi	This VI, *which is only available in the COMP13X.LLB library,* should be modified and executed for non-exclusive GPIB operation.
	GPIB Send.vi	Manages sending and receiving of ASCII strings from the actual instrument.
Model 136	Set 136 A via GPIB.vi	Configures the A setpoint.
Model 136	Set 136 B via GPIB.vi	Configures the B setpoint.
	Set 13X Interval via GPIB.vi	Configures the sampling interval setting.
	Set 13X HI via GPIB.vi	Configures the HI setpoint.
	Set 13X Length via GPIB.vi	Configures the sensor length.
	Set 13X LO via GPIB.vi	Configures the LO setpoint.

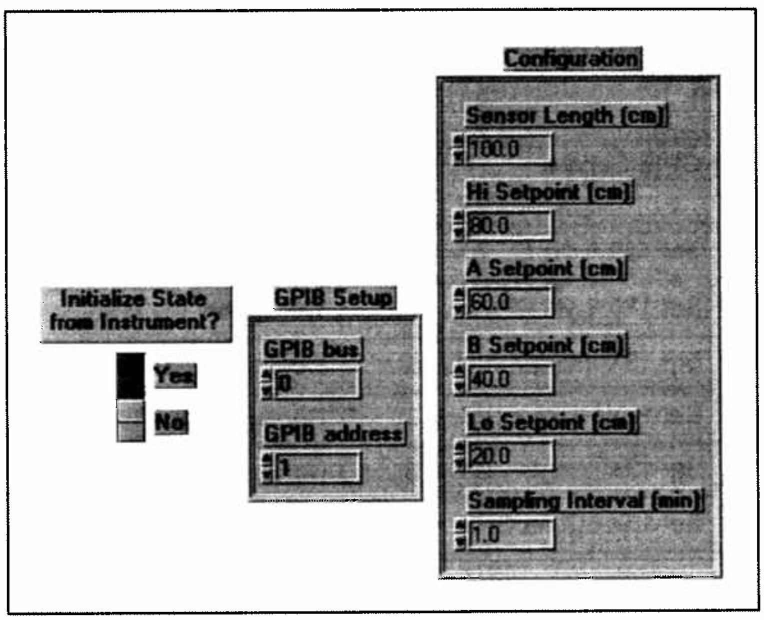
The *Model 13X via GPIB.vi* in the MODEL13X.LLB library should be used if the Model 135/136 has exclusive control of the GPIB bus, i.e. is the only device present and operating on the bus.

An additional library provided on the LabVIEW floppy disk, COMP13X.LLB, contains all the VI's included in the MODEL13X.LLB library along with the additional *Non-exclusive loop control.vi* and reusable version of the *Model 13X via GPIB.vi*. The *Non-exclusive loop control.vi* provides a control example which can be customized to coexist with multiple devices on one GPIB bus. The exact design of the non-exclusive operation is dependent upon the specific devices you may have connected to the bus.

When running the VI it is important to operate the instrument using the VI and not via the actual instrument front panel. Otherwise, the VI and the actual instrument may not be synchronized. The only exceptions to this rule are operation of the sampling mode toggle switch or operation of the relay control rotary switch if manual override becomes necessary. The sampling mode toggle switch should be set via the front panel of the actual instrument to the mode desired by the operator. The VI's representation of the sampling mode toggle switch overrides any actual front panel setting by forcing the actual instrument to perform an immediate measurement when placed in the UPDATE position.

5.2.1 Launching and initializing the GPIB VI

First, make sure the Model 136 is connected to the GPIB bus and that the unit is powered on. Independent of whether you use the exclusive or non-exclusive mode of execution, the initialization method of the Model 135/ 136 should be determined. To set the initialization method, scroll to the area above the virtual front panel and observe the virtual controls as illustrated below (the version of the *Model 13X via GPIB.vi* provided in



COMP13X.LLB provides inputs for the initialization method and input/ output for the configuration). The *Initialize State from Instrument?* switch allows the user to select whether the instrument is initialized from the current settings of the actual instrument or from the controls available from the VI. If the *Yes* option is selected, the VI will initialize all settings from the actual instrument. If the *No* option is selected, the user should enter all data in the control fields (*Sensor Length*, *Hi Setpoint*, etc.) in the indicated units. The user should also select the correct GPIB bus and primary address (see page 30 for instructions on setting the Model 135/136 primary address). If only one GPIB interface is present in the host computer, the GPIB bus is normally set to 0. Refer to your LabVIEW documentation for more information on how to determine the GPIB bus setting appropriate for your computer. After setting the initialization parameters, the user may then start the VI. Please refer to your LabVIEW documentation for instructions on how to start and control the execution of VI's.

5.2.2 Interacting with the running VI

While the VI is running the user may manipulate the virtual toggle and rotary switches in the same manner as required for the front panel operation of the actual instrument. See the Operation section of this manual for instructions on operating the front panel controls, however, please note that there are some minor differences discussed below.

The RAISE/LOWER toggle switch functions slightly different in the VI. If the RAISE/LOWER toggle switch is moved from the center position to the RAISE or LOWER position, then the display changes to show the appropriate parameter. After approximately 4 seconds in the RAISE or LOWER position, the display will begin incrementing or decrementing by tenths. After approximately 12 additional seconds, the display will begin incrementing/decrementing by ones. Move the RAISE/LOWER toggle switch back to the center position to stop the incrementing or decrementing function.

As previously discussed, *only the sampling mode toggle switch or fill toggle switch should be manipulated via the front panel of the actual instrument while the VI is running*. The VI representation of the sampling mode toggle switch forces the actual instrument to perform an immediate measurement when placed in the UPDATE position. When placing the VI switch in the UPDATE position, it must be left in the UPDATE position for at least a couple of seconds in order to be recognized. Simply place the switch back in the SAMPLE position to return to the operational mode specified via the actual instrument's sampling mode toggle switch.

The virtual instrument's FILL LED indicator is only accurate if the fill toggle switch is in the AUTO position. There is no remote monitoring or control of the manual override states of the fill toggle switch available through the communication command set.

As a more convenient option for controlling the settings, the user may scroll to the area above the VI and enter the values for the Sensor Length, Hi Setpoint, Lo Setpoint, and Interval directly in the control fields (please observe the specified units). Any changes in the fields are recognized and sent to the actual instrument in the form of the appropriate command string. Any settings changed by the VI virtual panel toggle switches or control fields are saved in permanent memory in the actual instrument. The control fields and toggle switches function whether the VI is run exclusively or non-exclusively on the GPIB bus.

If the VI is executed exclusively, then the VI may be gracefully stopped by using the STOP toggle switch in the lower left corner of the VI. After stopping the VI, this switch must be placed back in the up position in order to restart the VI. If you are executing the VI in a non-exclusive polling loop on the GPIB bus, then the STOP toggle switch has no function and the user should control the execution of the VI from the controlling parent VI(s).

5.2.3 Running multiple GPIB devices

The *Model 13X via GPIB.vi* in the MODEL13X.LLB library is designed to have exclusive control of the GPIB bus. AMI recognizes this is generally not the case for a GPIB bus configuration. Therefore, the *Non-exclusive loop control.vi* example is provided in the COMP13X.LLB library to demonstrate how the *Model 13X via GPIB.vi* can be cooperatively executed on a GPIB bus with multiple devices connected.

In order to use multiple devices from the same host computer and GPIB bus, the Model 135/136 should be set to a unique primary address. In addition to modifications required to use other devices present on the bus, the user should modify the *Non-exclusive loop control.vi* to both initialize and then execute the *Model 13X via GPIB.vi* at a regular interval. The longer the interval between execution, the less responsive the VI will appear. This is due to the fact that the VI assumes periodic execution in order to poll the virtual switches and control fields for user-initiated changes. The suggested period between execution is 1 second in order to exhibit a reasonable level of responsiveness from the VI. The requirement to constantly poll a virtual panel for changes is an unfortunate requirement for running these types of continuously executing interfaces using LabVIEW.

6 Service Guide

The procedures in this section should only be performed by Qualified Service Personnel (QSP).

6.1 Troubleshooting Procedures

The following paragraphs serve as an aid to assist QSP in troubleshooting a potential problem with the Model 135/136. If the QSP is not comfortable with troubleshooting the system, you may contact an Authorized AMI Technical Support Representative for assistance. Refer to "Additional Technical Support" on page 53.

This instrument contains CMOS components which are susceptible to damage by Electrostatic Discharge (ESD). Take the following precautions whenever the cover of the instrument is removed.

1. Disassemble the instrument only in a static-free work area.
2. Use a conductive workstation or work area to dissipate static charge.
3. Use a high resistance grounding wrist strap to reduce static charge accumulation.
4. Ensure all plastic, paper, vinyl, Styrofoam® and other static generating materials are kept away from the work area.
5. Minimize the handling of the instrument and all static sensitive components.
6. Keep replacement parts in static-free packaging.
7. Do not slide static-sensitive devices over any surface.
8. Use only antistatic type solder suckers.
9. Use only grounded-tip soldering irons.

6.1.1 No level reading

1. Ensure that the sensor is immersed in liquid helium. If the sensor is immersed and/or cooled, then proceed to step 2.

   Note

   When the sensor is not cooled, the instrument will enter into the sensor burnout protection mode and turn off the sensor current. Refer to paragraph 3.1 of the Operation section for a description of this mode.

2. Check the sensor connections. With the sensor at room temperature, check the following resistances between sensor leads:

   RED to BLUE = approximately 5 ohms
   BLUE to YELLOW = 13.75 ohms x Active Length (inches)
   YELLOW to BLACK = approximately 0.7 ohms
   RED to BLACK = (RED to BLUE) + (BLUE to YELLOW)

   If the indicated conditions do not exist, contact an Authorized AMI Technical Support Representative.

   Note

   If sensor lead wires in excess of few feet are connected, the above figures may not be applicable.

3. Ensure that the instrument is energized from a live power source of proper voltage. The unit configured voltage is indicated on the rear panel.

   Warning

   If the instrument has been found to have been connected to an incorrect power source, return the instrument to AMI for evaluation to determine the extent of the damage. Frequently, damage of this kind is not visible and must be determined using test equipment. Nevertheless, connecting the instrument to an incorrect power source could damage the internal insulation and/or the ground requirements, thereby, possibly presenting a severe life-threatening electrical hazard.

4. Verify continuity of the line fuse, F2, located on the instrument printed circuit board.

Warning

This procedure is to be performed only when the instrument is completely de-energized by removing the power-cord from the power receptacle. Failure to do so could result in personnel coming in contact with high voltages capable of producing life-threatening electrical shock.

a. Ensure the instrument is de-energized by disconnecting the power cord from the power source. Disconnect the power cord from the connector located on the rear panel of the instrument.

b. Remove the instrument top cover and check the fuse F2 for continuity.

c. If the fuse is bad, replace with a 500 mA IEC 127-2 Type F Sheet II 5x20mm fuse.

Warning

Installing fuses of incorrect values and ratings could result in damage to the instrument in the event of component failure and/or a safety hazard.

d. Replace the fuse(s) and securely fasten the instrument top cover. Reconnect the power-cord.

6.1.2 Erratic or erroneous level reading

1. Ensure that the sensor is connected properly to the rear panel SENSOR connector, J1 (see the Rear Panel Layout on page 4 and the pinout diagram in the *Appendix* on page 56).

Note

A significant number of trouble calls are the result of the sensor not properly connected to J1 on the rear panel. The proper positioning of the sensor wires and proper solder connections are critical to the proper operation of the Model 135/136.

2. Ensure there are no ice formations on the sensor. Ice formations on the sensor inhibit sensing element thermal propagation thereby producing incorrect readings. If ice formation has occurred, the ice must be removed. If ice formation of the sensor is likely to reoccur, refer to the operation section of the manual under dirty sensor operation.

3. Check for a dirty sensor. If the sensor collects oil, water, etc., the sensor could possibly not operate correctly. Refer to page 20 for a discussion of the optional dirty sensor operational mode.

4. Ensure the sensor is not installed in a restricted area which prohibits the level of helium around the area of the sensor to be an accurate representation of the level to be measured. The gas produced by the sensor when the sensor current is on can depress the liquid level.

5. Ensure the sensor is installed with lead wires at the top. Due to the physical construction of the AMI LHe sensor, a reading of 100% will always result if the sensor is installed upside down.

6.1.3 Controller output does not energize

Warning

Model 136

This procedure is to be performed only when the instrument is completely de-energized by removing the power-cord from the power receptacle. Failure to do so could result in personnel coming in contact with high voltages capable of producing life-threatening electrical shock.

1. Verify continuity of controller output fuses, F1 and F3, located on the instrument printed circuit board.

    a. Ensure the instrument is de-energized by disconnecting the power cord from the power source. Disconnect the power cord from the connector located on the rear panel of the instrument.

    b. Remove the instrument top cover and check the fuses F1 and F3 for continuity.

    c. If the fuse is bad, replace with a 1.25 A IEC 127-2 Type F Sheet II 5x20mm fuse.

    d. Check your connected equipment for compliance with the output receptacle rating.

Caution

Installing fuses of incorrect values and ratings could result in damage to the instrument in the event of component failure.

2. Replace the fuse and securely fasten the instrument top cover. Reconnect the power-cord.

6.1.4 Unit not responding to communications

1. Verify your communications cable integrity and wiring. See the *Appendix* for DB-25 to DB-9 translation for RS-232 cables.

2. Check to make sure you are sending the correct termination to the instrument. If you are using the RS-232 option, make sure the echo feature is set correctly for your application and the baud rate matches the setting of the host device. If you are using the IEEE-488 option, check the primary address setting and make sure the controller software is set to query the instrument at the primary address selected.

3. Check your host communications software and make sure it is recognizing the return termination characters from the instrument. For RS-232 communication, the return termination characters are *<CR><LF>*. For IEEE-488, the return message termination characters are *<LF>* with EOI.

4. If the instrument is responding repeatedly with *-8* as the return message, try a device clear command (DCL) or powering the instrument off and then back on. Be sure you are sending valid commands.

5. If you experience continued trouble with the IEEE-488 option, you may have an incompatible IEEE-488 card in your host computer. In the past, AMI has found subtle differences between manufacturers of IEEE-488 cards that have introduced communication errors. AMI attempts to establish compatibility with as many products as possible, however, it is difficult to test every card available. Contact AMI directly if you have thoroughly checked your setup and continue to experience problems with the IEEE-488 option.

6. Version 2.6 of the NI-488.2 drivers from National Instruments has known bugs that prevent the correct operation of the IEEE-488 interface when executed from LabVIEW. Contact National Instruments for workarounds appropriate for your configuration.

If the cause of the problem cannot be located, contact an AMI customer service representative for assistance. DO NOT SEND A UNIT BACK TO AMI WITHOUT PRIOR RETURN AUTHORIZATION.

6.2 Custom Instrument Configurations

6.2.1 Modifying the line voltage requirements

Warning

Before removing the cover of the instrument, remove the power from the instrument by disconnecting the power cord from the power receptacle. Failure to do this could expose the user to high voltages and could result in life-threatening electrical shock.

Caution

The Model 135/136 instrument operates on 50-60 Hz power and may be configured for 100-120 VAC or 200-240 VAC ±10%. The power requirements for each instrument are marked on the rear panel. Be sure the instrument's power requirements match your power source prior to plugging in the line cord. Do not fail to connect the input ground terminal securely to an external earth ground.

If the instrument operating voltage needs to be changed, ensure the instrument is de-energized by disconnecting the power cord from the power source. Remove the instrument cover and slide the voltage selector switch on the main printed circuit board to the proper voltage. Replace the instrument cover and *indelibly mark the rear panel indications to match the new configuration.*

6.2.2 Enabling dirty sensor operational mode

Warning

Before removing the cover of the instrument, remove the power from the instrument by disconnecting the power cord from the power receptacle. Failure to do this could expose the user to high voltages and could result in life-threatening electrical shock.

To operate in this mode, de-energize the instrument and remove the cover. Place a jumper on W2 of the printed circuit board vertically-mounted directly behind the front panel. Replace the cover and energize the instrument. The operation in this mode is not detectable from the front panel. Each time the sensor current is energized in the SAMPLE mode, a high current is briefly shunted to the sensor before the actual level measurement cycle is initiated.

6.2.3 Changing time adjustments from minutes to hours

Warning

Before removing the cover of the instrument, remove the power from the instrument by disconnecting the power cord from the power receptacle. Failure to do this could expose the user to high voltages and could result in life-threatening electrical shock.

The Model 135/136 can be configured to use hours for the time settings, as opposed to the factory setting of minutes. To configure for hours operation, de-energize the instrument and remove the cover. Place a jumper between pins 1 and 2 of W1 (HR position) on the printed circuit board vertically-mounted directly behind the front panel. Replace the cover and energize the instrument. All time-based settings should now operate in hours mode.

6.3 Additional Technical Support

If the cause of a problem cannot be located, contact an AMI Technical Support Representative at (865) 482-1056 for assistance. The AMI technical support group may also be reached by Internet e-mail at **support@americanmagnetics.com**. Additional technical information, latest software releases, etc. are available at the AMI World Wide Web site at:

http://www.americanmagnetics.com

Do not return the Model 135/136 or other liquid helium level system components to AMI without prior return authorization.

6.4 Return Authorization

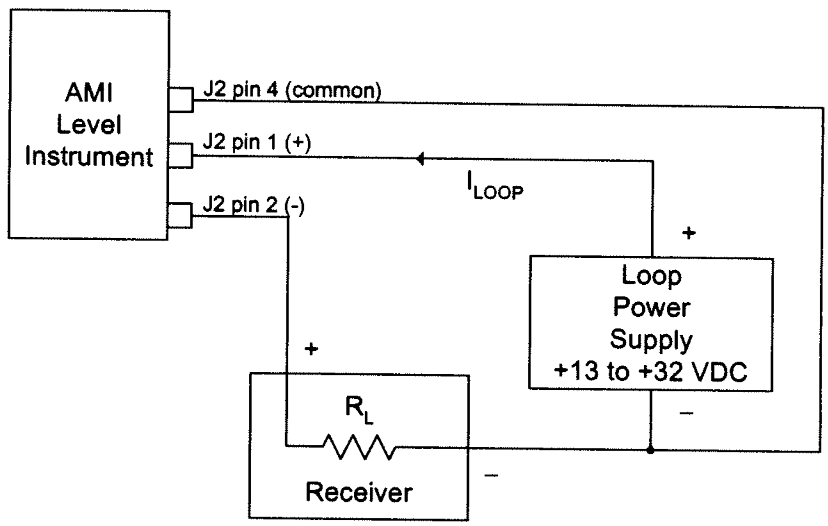
Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive proper attention. Please call an AMI representative at (865) 482-1056 for a return authorization number before shipping any item back to the factory.

A.1 4-20 ma Current Loop Option

The 4-20 mA output utilizes pins 1 and 2 of connector J2. When the Model 135/136 is configured for the 4-20 mA current loop option, the 0-10 VDC analog output from connector J2 is not available. The figure below shows the wiring diagram and the voltage requirements for the power supply and receiver.

Caution

It is extremely important to observe all polarities and to not exceed +32 VDC for the loop power supply in order to prevent damage to the 4-20 mA driver circuit.

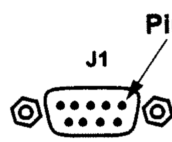


Note

For maximum immunity to external electrical and electromagnetic disturbances, all external cabling (except for the AC input and controller output) should be shielded. The cable shield should be connected to the chassis of the instrument by connecting to the D-sub connector shell.

A.2 Sensor Connector J1 Wiring

Pin	Function
1	Sensor I+ (Red)
2	Not used
3	Not used
4	Not used
5	Not used
6	Sensor V- (Yellow)
7	Sensor I- (Black)
8	Sensor V+ (Blue)
9	Not used

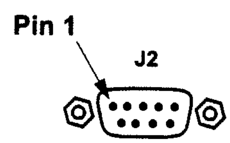


Warning

Although the sensor connector terminals are isolated from earth ground and therefore touching one terminal is not hazardous, the voltage between terminals is at a hazardous potential. The sensor connector is for use with an AMI LHe sensor and the wiring for the sensor is to have no live parts which are accessible. Conductors connected to its terminals must be insulated from user contact by basic insulation rated for 150 VAC (Category I).

A.3 Auxiliary Connector J2 Pinout

Pin	Function
1	4-20 mA current loop input (optional feature)
2	4-20 mA current loop output (optional feature)
3	0-10 VDC output (optional feature)
4	0-10 VDC output common (optional feature)
5 & 6	Lo level relay contacts (dry)
7 & 8	Hi level relay contacts (dry)
9	Not used



The HI level and LO level contacts are provided for external use by the customer. When a HI or LO level condition exists, the respective contact pairs are closed. All setpoints have 1/2 mm hysteresis, therefore the respective contact pairs may "chatter" if the liquid sloshes, bubbles, etc.

The HI level and LO level contacts also provide positive indication of a power-off condition. With a power-off condition, *both* the HI level and LO level contacts will be *closed*, which is a state unique to the power-off condition.

The following table provides the specifications for the contacts:

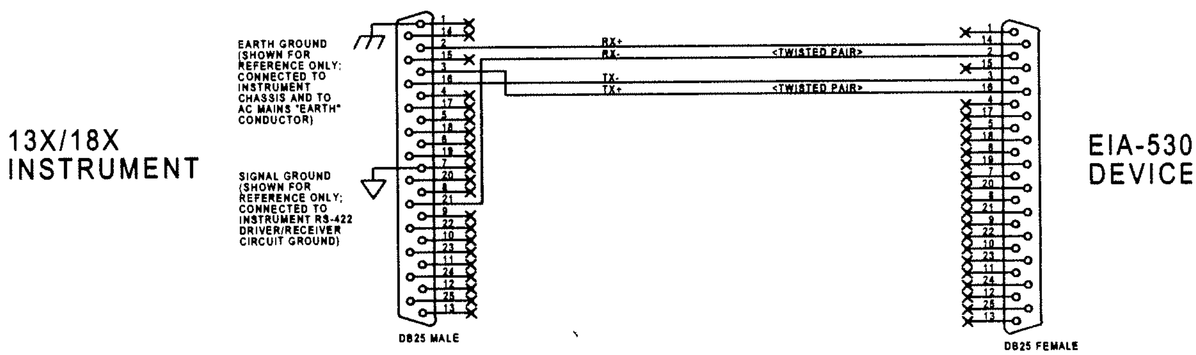
Max switching VA	10
Max switching voltage	30 VAC or 60 VDC
Max switching current	0.5 A
Max continuous current	1.5 A

A.4 RS-232 Cable DB-25 to DB-9 Translation

DB-25 Pin	DB-9 Pin
2	3
3	2
4	7
5	8
6	6
7	5
8	1
20	4
22	9

All other pins on the DB-25 connector are unused. This is standard PC modem cable wiring.

A.5 RS-422 Cable Wiring



13X/18X CONNECTOR	EIA-530 CONNECTOR	
RX+ (PIN 2)	TX+ (PIN 14)	TWISTED PAIR
RX- (PIN 21)	TX- (PIN 2)	
TX+ (PIN 3)	RX+ (PIN 16)	TWISTED PAIR
TX- (PIN16)	RX- (PIN 3)	

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AMI HELIUM VAPOR COOLED CURRENT LEADS

Installation, Operation and Maintenance Instructions

I. INTRODUCTION

The American Magnetics, Inc. (AMI) helium vapor cooled current leads are designed to introduce high currents into liquid helium environments with a minimum of liquid helium loss. This is accomplished by using the heat capacity of the cold helium boil-off gas to cool the current leads.

II. SPECIFICATIONS

A. Table 1 lists the specifications and shows dimensional references for AMI standard vapor cooled current leads. Dimensional references in Table 1 are shown on Figure 1. Custom designed or special order current leads may have dimensions and specifications that vary from those listed. However, the remainder of the information in these Installation, Operation and Maintenance Instructions is applicable.

B. A voltage drop of 0.2 volts per lead at the rated current is typical.

C. A pressure drop of approximately 2mm of mercury (0.03 psi) is developed through the leads at the rated current.

D. Operating temperature range is 300K to 4.2K.

III. INSTALLATION

A. Carefully remove the current leads from the shipping carton and ensure all packaging material is removed..

B. Ensure that the vapor passages do not have any foreign material lodged in them. Check the passage-ways by blowing dry compressed air through the passage-ways.

> <u>NOTE:</u> *Compressed air with high moisture content may cause water vapor to collect in the passage-ways which may subsequently freeze and cause blockage.*

Model Number		L-50	L-75	L-100	L-150	L-200	L-250	L-500	L-1000	L-2000	L-3000	L-5000
Amperes		50	75	100	150	200	250	500	1000	2000	3000	5000
~Helium consumption, liters/hr., (pair of leads)		0.18	0.25	0.37	0.48	0.64	0.8	1.6	3.2	6.4	9.6	16
Type (see figures above)		A	A	A	A	A	A	A	B	B	B	B
DIMENSIONS IN INCHES	A	1/4	1/4	1/4	1/4	3/8	3/8	1/2	1/2	1/2	1/2	3/4
	B	1-1/2	1-1/2	1-1/2	1-1/2	2	2	3	3	3	3-3/4	4-1/2
	C	1	1	1	1	1-1/4	1-1/4	1-1/2	2	2-1/2	3	3
	D								1	1	1-1/2	1-1/2
	E	9/32	9/32	9/32	9/32	9/32	9/32	9/16	9/32	7/16	7/16	7/16
	F	3/8	3/8	3/8	3/8	1/2	3/4	3/4	3/4	3/4	1	1
	G	3/8	3/8	3/8	3/8	1/2	1/2	1/2	7/8	1-1/8	1-1/4	1-1/2
	H	1/4	1/4	1/4	1/4	3/8	1/2	1/2	1/2	3/4	1	1
	I								2-1/4	2-1/2	2-5/8	3
	J								1-3/4	2	2-1/8	2-1/4
	K	1/4 NPT	1/4 NPT	1/4 NPT	1/4 NPT	3/8 NPT	3/8 NPT	1/2 NPT	1	1-1/4	1-3/8	1-5/8
	L	7/8	7/8	7/8	7/8	1	1	1-3/16	5/8	5/8	5/8	5/8
	M	9/16	9/16	9/16	9/16	9/16	9/16	3/4	3/8	3/8	3/8	3/8
	N								9/32	9/32	9/32	9/32
	O	1/4	1/4	1/4	1/4	3/8	3/8	1/2	3/4	1	1-1/8	1-3/8
	R					0.201	0.201	0.201	9/32	13/32	17/32	17/32
	S	1	1	1	1	1	1	1	1-1/2	1-1/2	1-1/2	1-1/2
	T	1/16	1/16	1/16	1/16	1/8	1/8	1/8	1/4	1/4	1/4	1/4
	U					1/4	1/4	1/4	1/2	1/2	1/2	1/2
	V	16-5/8	16-5/8	16-5/8	16-5/8	16-5/8	16-5/8	17-1/2	19-1/2	19-1/2	19-1/2	19-1/2
	W	Adjust.	Adjust.	Adjust.	Adjust.	Adjust.	Adjust.	Adjust.	1-1/2	2	2	2
	X	1/4	1/4	1/4	1/4	3/8	3/8	1/2	3/4	1	1-1/8	1-3/8

TABLE 1
HELIUM VAPOR COOLED CURRENT LEAD SPECIFICATIONS

*Helium consumption is for a pair of leads when energized at operating current. Helium consumption is approximately equal to 1.6 x 10-3 liter per hour per lead. Helium consumption at zero current is approximately 40% of operating consumption.

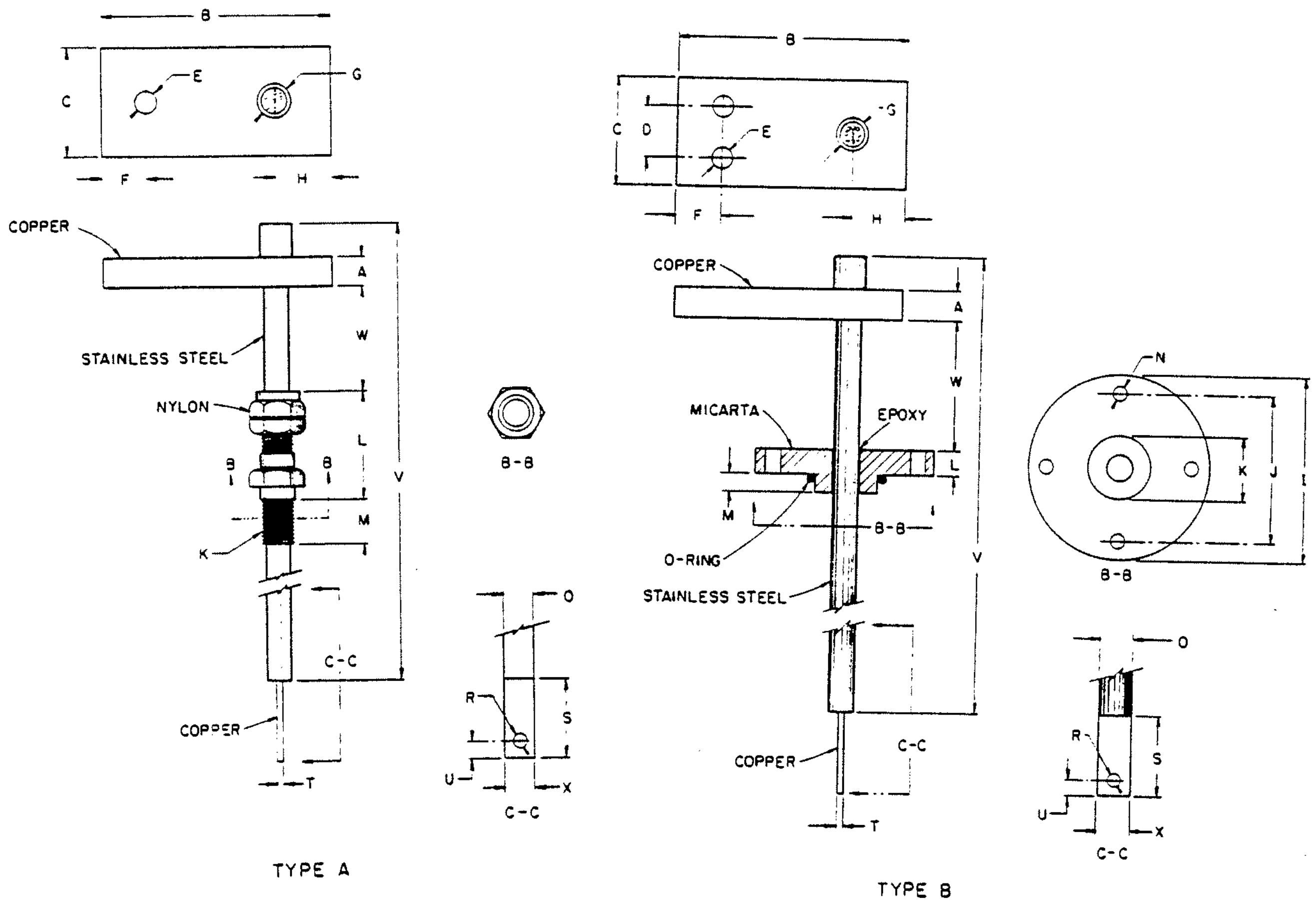
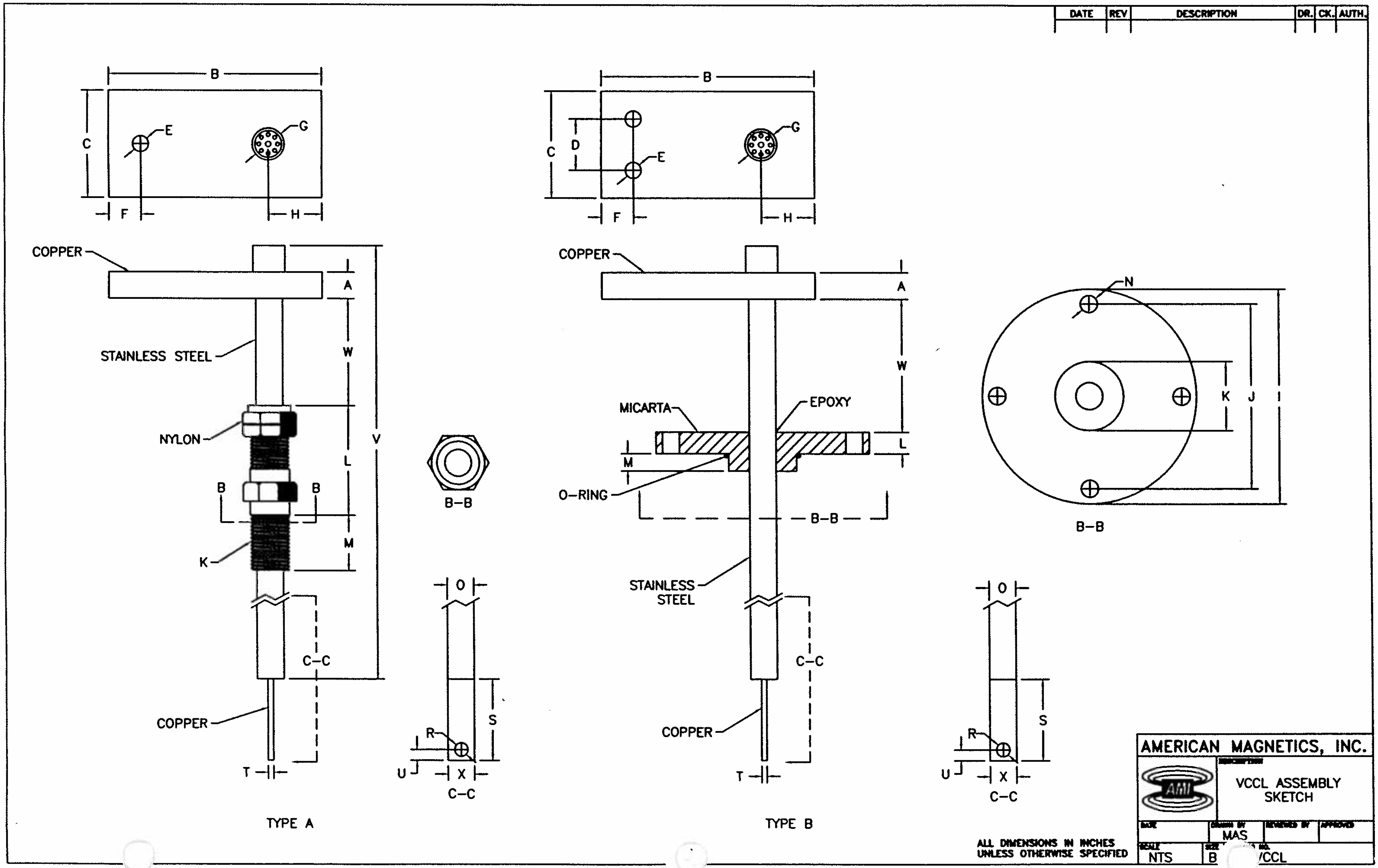


FIGURE 1
DIMENSION REFERENCES OF STANDARD
HELIUM VAPOR COOLED CURRENT LEADS



DATE
REV
DESCRIPTION
DR.
CK.
AUTH.
B
C
D
E
F
G
H
COPPER
A
W
STAINLESS STEEL
NYLON
L
V
B
B
M
K
C–C
COPPER
T
TYPE A
B–B
O
R
S
U
X
C–C
MICARTA
EPOXY
M
L
O–RING
B–B
STAINLESS
STEEL
C–C
COPPER
T
TYPE B
N
K
J
B–B
O
R
S
U
X
C–C
ALL DIMENSIONS IN INCHES
UNLESS OTHERWISE SPECIFIED
AMERICAN MAGNETICS, INC.
VCCL ASSEMBLY
SKETCH
MAS
NTS
B
VCCL

C. Position the current leads into the helium dewar and secure them in position either with nylon bushings or by bolting through the micarta flange.

<u>CAUTION:</u> Ensure that the bottom of the vapor tube is positioned above the maximum liquid helium level. A liquid helium level above the bottom of the vapor tube will result in excessive helium loss until the level stabilizes below the end of the vapor tube.

D. Electrical connections to the bottom current lug should be made by bolting and soldering. Solder electrical connections with ordinary eutectic lead-tin or other low melting point solder.

<u>CAUTION:</u> A heat sink should be provided between the electrical connection and the vapor tube to keep the temperature below 400oF. The vapor tube is constructed with a lead-silver solder that melts at 430oF. Temperatures above 430o could result in damage to the vapor tube filaments.

<u>NOTE:</u> It is desirable to make as good an electrical connection as possible between the current lead connection flange and the load. A poor electrical connection may cause excessive helium loss.

<u>NOTE:</u> AMI can provide a 24 inch bus bar extension that will operate in either the superconducting or resistive mode. However, it should be noted that the use of a bus bar extension may cause the helium consumption to increase.

E. Electrical connections should be made by bolting or clamping cables, with proper terminations, to the top current lug.

<u>CAUTION:</u> Be sure all power supplies are de-energized before making or breaking electrical connection.

F. During cooldown, helium gas should be vented through the vapor cooled current leads. A short length of rubber tubing pointed downwards will create a helium gas trap and prevent the re-introduction of air into the system.

IV. OPERATION

The helium vapor cooled current leads are a passive system component. They are ready to carry the current to the load when properly installed. Upon initial operation and periodically thereafter the helium gas flow through the current leads should be checked and the flow balanced (i.e. equalized). Flow is adjusted by restricting, by any suitable means, the higher gas flow. All normal gas flow from the dewar should be vented through the current leads. An overpressure valve should be provided on the dewar to vent large amounts of helium gas that may be generated in an abnormal event (e.g. superconducting magnet quench).

> *CAUTION:* *When vapor cooled current leads are used with inductive loads such as superconducting magnets, special care should be taken to avoid thermal damage to the current leads. Gas blockage can result in overheating, deterioration or even complete burn-out of the current leads. The resulting inductive voltages in the load are dangerous and special care must be taken to ensure the magnet is completely discharged to avoid equipment damage and electrical shock.*

After gas flow has been initially balanced a frequent visual check for frost on the current lead is sufficient to assure safe operation. Alternatively, the voltage across each lead (from the top of the lead to the appropriate magnet terminal) may be monitored to avoid operating with an overheated condition.

> *CAUTION:* *If your experiment requires current reversing it is recommended that the AMI Model 610 current reversing switch be purchased. Manual disconnecting and switching of current leads is NOT recommended because of the potentially fatal voltages involved.*

V. MAINTENANCE

Periodically check and adjust the helium gas vapor flow through the leads to ensure they are balanced.

VI. TROUBLESHOOTING

If the vapor cooled current leads are properly installed and operated within the specification limits they will provide years of trouble free service. The leads are sealed, passive units and repair, other than by factory authorized personnel, is not recommended.

VII. WARRANTY

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of a failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. All warranty repairs are F.O.B. Oak Ridge, Tennessee.

VIII. RETURN AUTHORIZATION

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive the proper attention. Please call an AMI representative at (423) 482-1056 for a return authorization before shipping any item back to us.

CE

Declaration of Conformity

Application of Council Directive:	72/73/EEC
Standard to which Conformity is Declared:	EN 61010-1: 1993 w/A1, A2
Manufacturer's Name:	American Magnetics, Inc.
Manufacturer's Address:	112 Flint Road, P.O. Box 2509 Oak Ridge, TN 37831-2509 U.S.A.
Type of Equipment:	Power Supply Programmer
Model Number:	Model 420

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive and Standard.

Place:	Oak Ridge, Tennessee, U.S.A.	Signature:	Charles Hargis
Date:	October 15, 1999	Full Name:	Charles H. Hargis
		Function:	Quality Assurance Manager

AMI Model 420 Factory Configuration

Magnet Job No.: 9087 Model 420 Serial No.: 01-0712-1

3.2.1 SETUP Menu: Supply

3.2.1.1 Power Supply Selection:

- [ ] AMI 12100PS
- [ ] AMI 12200PS
- [x] AMI 4Q05100PS
- [ ] AMI 10100PS
- [ ] AMI 10200PS
- [ ] HP 6260B
- [ ] Kepco BOP 20-5M
- [ ] Kepco BOP 20-10M

- [ ] Custom: ______ (The following values only apply to Custom selection.)

3.2.1.2 Minimum Output Voltage (V): ______

3.2.1.3 Maximum Output Voltage (V): ______

3.2.1.4 Minimum Output Current (A): ______

3.2.1.5 Maximum Output Current (A): ______

3.2.1.6 V-V Mode Input Range (V): [ ] +0.000 to + 5.000 [ ] +0.000 to +10.000 [ ] −5.000 to +5.000 [ ] −10.000 to +10.000

3.2.2 SETUP Menu: Load

3.2.2.1 Stability Setting (%): 0

3.2.2.2 Coil Constant (kG/A): .9068

3.2.2.3 Current Limit (A): 77.2

3.2.2.4 Persistent Switch Installed?: [x] YES [ ] NO

3.2.2.5 Persistent Switch Current (mA): 46

3.2.2.6 Persistent Switch Heated Time (s): 15

3.2.2.7 Enable Quench Detect?: [x] YES [ ] NO

3.2.2.8 Energy Absorber Present?: [ ] YES [x] NO

3.2.3 SETUP Menu: Misc

3.2.3.1 Display Contrast (%): 80

3.2.3.2 Specify Ramp Rate In?: [x] Seconds [ ] Minutes

3.2.3.3 Field Units: [x] Kilogauss [ ] Tesla

3.2.4 SETUP Menu: Comm

3.2.4.1 IEEE-488 Address (0-30): 22

3.2.4.2 Serial Baud Rate: [ ] 1200 [ ] 2400 [ ] 4800 [x] 9600

3.2.4.3 Serial Data Bits/Parity: [ ] 7/Even [ ] 7/Odd [x] 8/None

3.2.4.4 Serial Stop Bits: [x] 1 [ ] 2

3.2.4.5 Serial Handshaking: [x] None [ ] SW (XON/XOFF)

3.3.1 Ramping Controls

3.3.1.1 Voltage Limit (V): 5

3.3.1.2 Ramp Rate [[x] A [ ] kG [ ] T / [x] sec [ ] min]: .1613

3.3.3.1 Programmed Current/Field [[x] A [ ] kG [ ] T]: 5.0

Brian Hannah
Technician's Signature

11 / 2 / 01
Date

Getting Started Using the AMI Model 420

ongratulations on the purchase of the AMI Model 420 Digital Power Supply Programmer. This programmer has been specifically designed for use with superconducting magnet applications. AMI has the following key suggestions to speed your learning curve for using the Model 420.

If you purchased your unit as part of a magnet system from AMI, the Setup Menu configuration and operating parameters will arrive preset for your application. You should not have to change any of the parameters in the Setup Menu. See Section 3.2.5 in the manual for an example setup configuration.

IMPORTANT - Before adjusting any parameters you should refer to the appropriate section of the manual to become familiar with the related functionality. This instrument is a powerful and complex tool. It is advisable to **READ FIRST** then **PLAY** with the programmer connected to an electrical short (see Section 2.7). This should be done prior to operating your magnet system.

Required Reading Checklist

(Checked items are directly related to your system)

System Type	Installation
☐ 1. AMI Unipolar supply without energy absorber	sec. 2.5.1
☐ 2. AMI Unipolar supply with AMI 601 energy absorber	sec. 2.5.2
☐ 3. AMI Unipolar supply with AMI 600/620 energy absorber	sec. 2.5.3
☐ 4. AMI Unipolar supply with AMI 610/630 energy absorber with current reversing switch	sec. 2.5.4
☒ 5. AMI High-current, Four-quadrant supply	sec. 2.5.5
☐ 6. Low-current, High-res four-quadrant supply (Kepco)	sec. 2.5.6
☐ 7. Non-AMI power supplies	sec. 2.5.7

Pitfalls to Avoid

- *The Setup Menu is used incorrectly* - Operational limits typically set by the user for magnet operation are specified by the user in the LOAD submenu, not the SUPPLY menu.
- *Have problems using a persistent switch* - The programmer must be informed that a persistent switch is present, and the switch heating time and switch heating current must be set. This is done through the LOAD submenu. The switch heater output of the Model 420 must also be connected to the magnet (see Table A-1, pins 9 & 10).

If you have read the manual and problems occur then refer to the Troubleshooting portion of this manual, Section 5.2. If problems still persist then feel free to call AMI for technical assistance at (865) 482-1056.

Model 420 Power Supply Programmer Configuration

AMI Order Number: TR 132849 Shipping Date: ________

Model 420 Serial #: 420/ 01-0712-1 Firmware Revision: 2.0

Input Power Requirements: 120VAC

Configuration Notes:

4Q05100 – 01-0712-2 – 120VAC

AMI Warranty

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. Since, however, AMI does not have control over the installation conditions or the use to which its products are put, no warranty can be made of fitness for a particular purpose, and AMI cannot be liable for special or consequential damages. All warranty repairs are F.O.B. Oak Ridge, Tennessee, USA.

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Foreword

Purpose and Scope

This manual contains the operation and maintenance instructions for the American Magnetics, Inc. Model 420 Digital Power Supply Programmer. The manual outlines the instructions for instrument use in various system configurations. Since it is not possible to cover all equipment combinations for all magnet systems, the most common configurations are discussed and the user is encouraged to contact an authorized AMI Technical Support Representative for information regarding specific configurations not explicitly covered in this manual.

Contents of This Manual

Introduction introduces the reader to the functions and characteristics of the instrument. It provides the primary illustrations of the front and rear panel layouts as well as documenting the performance specifications. Operational theory is also provided in the form of circuit diagrams.

Installation describes how the instrument is unpacked and installed in conjunction with ancillary equipment in typical superconducting magnet systems. Block-level diagrams document the interconnects for various system configurations.

Operation describes how the instrument is used to control a superconducting magnet. *All* instrument displays and controls are documented. The ramping functions, persistent switch heater controls, and the quench detect features are also presented.

Remote Interface Reference documents all remote commands and queries available through the RS-232 and IEEE-488 interfaces. A quick-reference summary of commands is provided as well as a detailed description of each.

Service provides guidelines to assist the user in troubleshooting possible system and instrument malfunctions. Information for contacting AMI Technical Support personnel is also provided.

The ***Appendix*** documents the rear panel connectors.

Applicable Hardware

The Model 420 has been designed to operate with a wide variety of switch mode and linear power supplies from a variety of manufacturers. However, not all compatible power supplies have been tested. The Model 420 Programmer has been tested and qualified with the following power supplies:

AMI Model 12100PS switching power supply (12V @ 100A)
AMI Model 12200PS switching power supply (12V @ 200A)
AMI Model 7.5-140PS switching power supply (7.5V @ 140A)
AMI Model 10100PS switching power supply (10V @ 100A)
AMI Model 10200PS switching power supply (10V @ 200A)
AMI Model 4Q-05100 4-Quadrant switching power supply (±5V @ ±100A)
Xantrex Model XFR 12-100 switching power supply (12V @ 100 A)
Xantrex Model XFR 12-220 switching power supply (12V @ 220 A)
Xantrex Model XHR 7.5-130 switching power supply (7.5V @ 130 A)
Hewlett-Packard 6260B linear power supply (10V @ 100 A)
Kepco BOP 20-5M 4-Quadrant linear power supply (±20V @ ±5A)
Kepco BOP 20-10M 4-Quadrant linear power supply (±20V @ ±10A)

Consult with an AMI Technical Support Representative for other approved power supplies.

General Precautions

Cryogen Safety

The two most common cryogenic liquids used in superconducting magnet systems are nitrogen and helium. Both of these cryogens are extremely cold at atmospheric pressure (–321°F and –452°F, respectively). The following paragraphs outline safe handling precautions for these liquids.

Personnel handling cryogenic liquids should be thoroughly instructed and trained as to the nature of the liquids. Training is essential to minimize accidental spilling. Due to the low temperature of these materials, a cryogen spilled on many objects or surfaces may damage the surface or cause the object to shatter, often in an explosive manner.

Inert gases released into a confined or inadequately ventilated space can displace sufficient oxygen to make the local atmosphere incapable of sustaining life. Liquefied gases are potentially extreme suffocation hazards since a small amount of liquid will vaporize and yield a very large volume of oxygen-displacing gas. Always ensure the location where the cryogen is used is well ventilated. Breathing air with insufficient oxygen content may cause unconsciousness without warning. If a space is suspect, purge the space completely with air and test before entry. If this is not possible, wear a forced-air respirator and enter only with a co-worker standing by wearing a forced-air respirator.

Cryogenic liquids, due to their extremely low temperatures, will also burn the skin in a similar manner as would hot liquids. Never permit cryogenic liquids to come into contact with the skin or allow liquid nitrogen to soak clothing. Serious burns may result from careless handling. Never touch uninsulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures. The vapors expelled during the venting process are sufficiently cold to burn flesh or freeze optic tissues. Insulated gloves should be used to prevent frost-bite when operating valves on cryogenic tanks. Be cautious with valves on cryogenic systems; the extremes of temperature they undergo causes seals to fail frequently.

In the event a person is burned by a cryogen or material cooled to cryogenic temperatures, the following first aid treatment should be given pending the arrival and treatment of a physician or other medical care worker:

1. If any cryogenic liquid contacts the skin or eyes, immediately flush the affected area gently with tepid water (102°F – 105°F, 38.9°C – 40.5°C) and then apply cold compresses.

2. Do not apply heat. Loosen any clothing that may restrict circulation. Apply a sterile protective dressing to the affected area.

3. If the skin is blistered or there is any chance that the eyes have been affected, get the patient immediately to a physician for treatment.

Containers of cryogenic liquids are self pressurizing (as the liquid boils off, vapor pressure increases). Hoses or lines used to transfer these liquids should never be sealed at both ends (i.e. by closing valves at both ends).

When pouring cryogenic liquids from one container to another, the receiving container should be cooled gradually to prevent damage by thermal shock. The liquid should be poured slowly to avoid spattering due to rapid boil off. The receiving vessel should be vented during the transfer.

Introduction of a substance at or near room temperature into a cryogenic liquid should be done with great caution. There may be a violent gas boil-off and a considerable amount of splashing as a result of this rapid boiling. There is also a chance that the material may crack or catastrophically fail due to forces caused by large differences in thermal contraction of different regions of the material. Personnel engaged in this type of activity should be instructed concerning this hazard and should always wear a full face shield and protective clothing. If severe spraying or splashing could occur, safety glasses or chemical goggles along with body length protective aprons will provide additional protection.

The properties of many materials at extremely low temperatures may be quite different from the properties that these same materials exhibit at room temperatures. Exercise extreme care when handling materials cooled to cryogenic temperatures until the properties of these materials under these conditions are known.

Metals to be used for use in cryogenic equipment application must posses sufficient physical properties at these low temperatures. Since ordinary carbon steels, and to somewhat a lesser extent, alloy steels, lose much of their ductility at low temperatures, they are considered unsatisfactory and sometimes unsafe for these applications. The austinetic Ni-Cr alloys exhibit good ductility at these low temperatures and the most widely used is 18-8 stainless steel. Copper, Monel®, brass and aluminum are also considered satisfactory materials for cryogenic service.

Magnet Quenches

When an energized superconducting magnet transitions from superconducting state to normal state, the magnet converts magnetic energy to thermal energy thereby rapidly converting the liquid helium to a vapor. When this phase transformation occurs, pressures can build rapidly in the cryostat due to the fact that one part of liquid helium will generate 782 parts of gaseous helium at STP. The cryostat must be designed to allow the generated vapor to rapidly and safely vent to an area of lower pressure. Cryostats are designed with pressure relief valves of sufficient capacity so as to limit the pressure transients within the container in order to prevent damage to the vessel. Operating a superconducting magnet in a cryostat without properly sized relief mechanisms or disabled relief mechanism is unsafe for the operator as well as for the equipment. If there is any doubt as to the sufficiency of the pressure relief system, contact the manufacturer of the magnet and cryostat for assistance.

Safety Summary

Superconducting magnet systems are complex systems with the potential to seriously injure personnel or equipment if not operated according to procedures. The use of cryogenic liquids in these systems is only one factor to consider in safe and proper magnet system operation. Proper use of safety mechanisms (pressure relief valves, rupture disks, etc.) included in the cryostat and top plate assembly are necessary. Furthermore, an understanding of the physics of the magnet system is needed to allow the operator to properly control the large amounts of energy stored in the magnetic field of the superconducting coil. The Model 420 Programmer has been designed with safety interlocks to assist the operator in safe operation, but these designed-in features cannot replace an operator's understanding of the system to ensure the system is operated in a safe and deliberate manner.

Recommended Safety Equipment

- First Aid kit
- Fire extinguisher rated for class C fires
- Leather gloves
- Face shield
- Signs to indicate that there are potentially damaging magnetic fields in the area and that there are cryogens are in use in the area.

Safety Legend

⚠ Instruction manual symbol: the product is marked with this symbol when it is necessary for you to refer to the instruction manual in order to protect against damage to the product or personal injury.

Hazardous voltage symbol.

~ Alternating Current (Refer to IEC 417, No. 5032).

O Off (Supply) (Refer to IEC 417, No. 5008).

| On (Supply) (Refer to IEC 417, No. 5007).

Warning

The Warning sign denotes a hazard. It calls attention to a procedure or practice, which if not correctly adhered to, could result in personal injury. Do not proceed beyond a Warning sign until the indicated conditions are fully understood and met.

Caution

The Caution sign denotes a hazard. It calls attention to an operating procedure or practice, which if not adhered to, could cause damage or destruction of a part or all of the product. Do not proceed beyond a Caution sign until the indicated conditions are fully understood and met.

1 Introduction

1.1 Model 420 Features

The AMI Model 420 Digital Programmer is a sophisticated power supply controller which allows an operator to manage a superconducting magnet system with unprecedented accuracy and ease of use. The Model 420 is the heart of a modern superconducting magnet system; when it is used in conjunction with a four-quadrant power supply, it provides for a degree of flexibility and accuracy previously unavailable in an economical commercial product.

1.1.1 Digitally-Controlled

The Model 420 is controlled by a microcomputer-based controller which controls all analog data conversion, display/keypad functions, communications I/O, generation of analog programming signals for the external power supply, and control law computations. The Model 420 incorporates digital signal processing (DSP) functions that provide for accurate control, low drift, and flexibility of use.

1.1.2 Superior Resolution and Stability

The Model 420 Programmer utilizes high resolution converters to translate signals between the analog and digital domains. Precision instrumentation techniques and potentiometer-free designs are employed throughout the instrument to ensure accurate signal translation for a wide range of conditions. The magnet current is sampled at a resolution of 0.2 mA (for a 100 A supply) and is front-panel programmable in 1 mA increments. All pause and hold functions are performed in the digital domain which provides for excellent stability and drift (<0.01%) of the programmed magnetic field.

1.1.3 Intuitive Human-Interface Design

The Model 420 Programmer was designed so as to simplify the interface where possible. All functions were analyzed and subsequently programmed so that the most commonly used functions are addressed with the least number of keystrokes. The menus are also presented in a logical fashion so that the operation of the Model 420 is intuitive to the user.

The provision of a velocity-sensitive rotary encoder on the front panel also allows the operator to fine-adjust many of the operating parameters of the magnet system.

1.1.4 Flexible Design

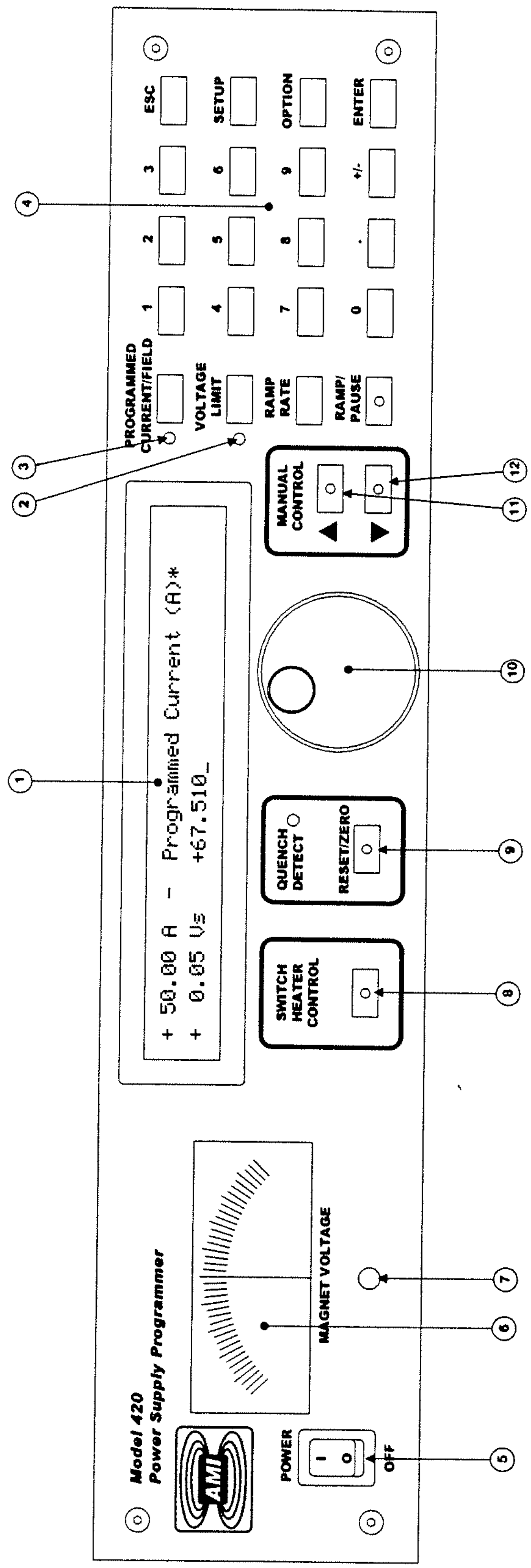
The Model 420 Programmer was engineered to be compatible with many magnet power supplies. From simple single-quadrant supplies, to more elaborate four-quadrant units, the Model 420 is user-configurable such that the operational paradigm complies with the specific magnet power supply system.

1.1.5 Standard Remote Interfaces

The Model 420 Programmer provides an RS-232 (or optional RS-422) serial port as well as an IEEE-488 parallel port as standard features. In contrast to other magnet power supply system designs, an expensive additional analog-to-digital conversion system is not required to collect data via a host computer. All settings can be controlled via the remote interfaces and the front panel can be remotely locked to prevent accidental operation. The Model 420 also provides trigger functions for data collection and/or logging during operation.

1.1.6 Programmable Safety Features

The Model 420 Programmer is designed to allow the operator to program the instrument from the front panel or remotely with operational parameters which must not be exceeded for the given conditions of the system. Once set, should an operator inadvertently attempt to take the magnet system to an excessive magnetic field strength or charge at an excessive voltage, the programmer will not accept the parameter and alert the operator that a value was rejected because it was outside the user-defined limits.


ESC
SETUP
OPTION
ENTER
1
2
3
4
5
6
7
8
9
0
.
+/-
PROGRAMMED CURRENT/FIELD
VOLTAGE LIMIT
RAMP RATE
RAMP/ PAUSE
MANUAL CONTROL
+ 50.00 A - Programmed Current (A)*
+ 0.05 Vs +67.510_
QUENCH DETECT
RESET/ZERO
SWITCH HEATER CONTROL
MAGNET VOLTAGE
Model 420
Power Supply Programmer
AMI
POWER
I
O
OFF
1
2
3
4
5
6
7
8
9
10
11
12

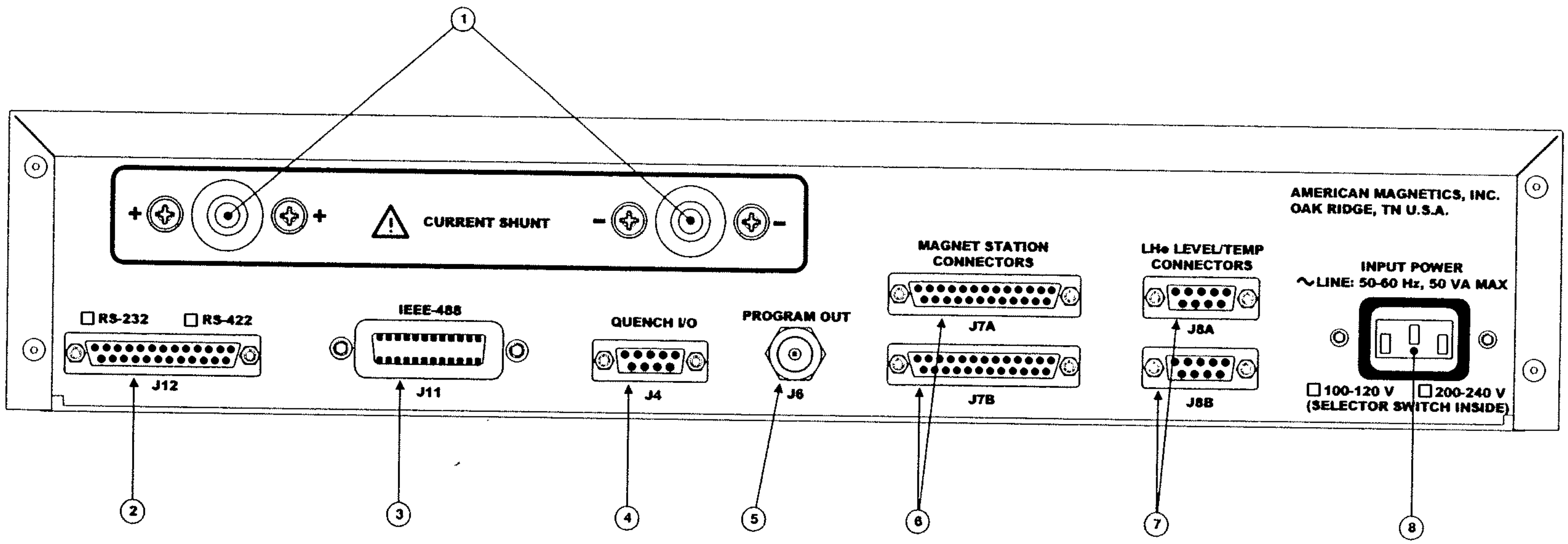


Table 1-2. Rear Panel Description

1	Current Shunt Terminals	5	Program Out BNC Female Connector
2	RS-232/422 25-pin Female D-sub Connector	6	Dual Magnet Station 25-pin Female D-sub Connectors
3	IEEE-488 Female Connector	7	Dual Auxiliary LHe Level/Temp 9-pin Male D-sub Connectors
4	Quench I/O 9-pin Female D-sub Connector	8	Input Power IEC-320 Male Connector

1.4 Model 420 Specifications @ 25 °C

Magnet Current Control Parameters	Standard Model 420 Configurations: Programmable Limits					
	± 5 A	± 10 A	± 100 A	± 200 A	± 600 A	± 2000 A
Measurement Resolution:	10 µA	20 µA	0.2 mA	0.4 mA	1.2 mA	4.0 mA
Accuracy (% of I_{max}):	0.1%	0.1%	0.1%	0.1%	0.005%	0.005%
Minimum Ramp Rate:	10 µA/min	10 µA/min	0.1 mA/min	0.1 mA/min	1 mA/min	1 mA/min
Maximum Ramp Rate:	1 A/sec	1 A/sec	10 A/sec	20 A/sec	60 A/sec	100 A/sec

Additional Specifications for all Configurations

Magnet Current Control

Temperature Coefficient:	0.01% of I_{max} / °C
Stability:	Better than 0.01% of I_{max} (40 min. warm-up)
Programming Resolution:	15 digits
Nominal Load Inductance Range:	0.5 to 100 Henries

Program Out Voltage

Programmable Limits:	–10 to +10 VDC (voltage-voltage mode)
Accuracy:	0.1% of V_{max}
Temperature Coefficient:	0.005% of V_{max} / °C
Resolution:	20 µV
Stability:	Better than 35 mV P-P when paused or holding

Magnet Voltage Measurement

Maximum Limits:	–20 to +20 VDC
Accuracy:	0.1% of V_{max}
Temperature Coefficient:	0.01% of V_{max} / °C
Resolution:	10 mV

Persistent Switch Heater Output

Programmable Limits:	0.1 to 100 mA DC
Accuracy:	0.5 mA
Temperature Coefficient:	0.02 mA / °C
Maximum Compliance:	13.5 V
Resolution:	0.1 mA
Optional External Supply Limits:	10 VA, 0.5 A max, 100 VDC max

Power Requirements

Primary:	100-120 or 200-240 VAC ±10% 50 - 60 Hz, 50 VA max
Memory Backup Battery:	3.6 Volt AA Lithium Cell

Physical

Dimensions:	89 mm H x 483 mm W x 191 mm D (3.5" H x 19" W x 10.75" D)
Weight:	4.2 kg (9.2 lbs.)

Environmental

Ambient Temperature:	Operating: 0 °C to 50 °C (32 °F to 122 °F) Nonoperating: –20 °C to 60 °C (–4 °F to 140 °F)
Relative Humidity:	80% up to 31 °C (88 °F), decreasing linearly to 50% at 50 °C (122 °F)
Altitude:	2 000 m (6562 ft.) Indoor use

Standards

EMI/EMC Standards:	EN50082-1 EN61000-4-2 EN61000-4-3 EN61000-4-4 EN55022, Class A
Safety Standard:	EN61010-1
Installation Category:	Pollution Degree 2, Overvoltage Category II as defined by IEC664

1.5 Operating Characteristics

The Model 420 Programmer has been designed to perform with various power supplies to allow the user the greatest degree of system flexibility. The power supply and programmer combination will be categorized by one of four forms: *single-quadrant*, *dual-quadrant*, *simulated four-quadrant*, and *true four-quadrant*. For sake of clarity, the term *quadrant* is defined as one of four areas of a cartesian coordinate system where the abscissa is current and the ordinate is voltage. Refer to Figure 1-1.

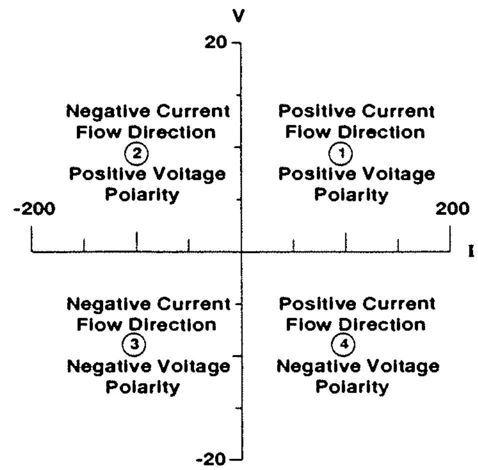


Figure 1-1. The four regions, or quadrants, of system operation.

1.5.1 Single-Quadrant Operation

The simplest form of a programmer-power supply system is the single quadrant system as illustrated in Figure 1-2. The system is comprised of a Model 420 Programmer, unipolar power supply, and superconducting magnet. This system allows current to flow in a single direction in the magnet thereby giving a magnetic field vector of varying magnitude but in a single direction. This corresponds to operating in quadrant 1 of Figure 1-1. The electrical energy can be stored as magnetic energy as fast as the magnet and power supply voltage will allow. In order to reduce the magnetic field, the magnetic energy is converted to electrical energy and then to thermal energy in the resistive elements of the system. The size of the resistive elements determines how fast the magnetic field can be collapsed and is typically very slow in the single-quadrant system.

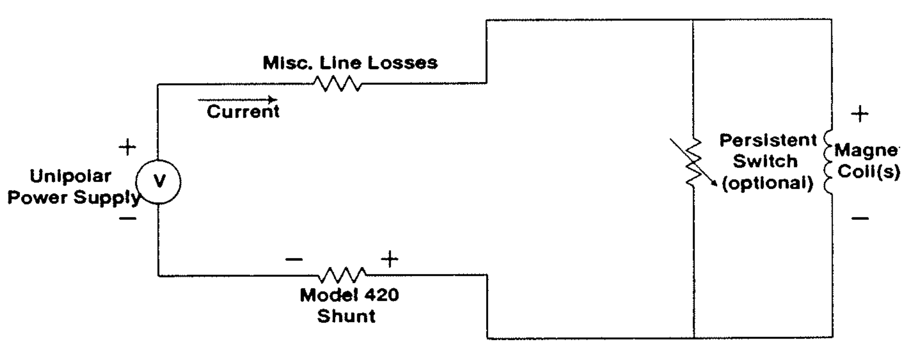


Figure 1-2. Single-Quadrant Magnet System

1.5.2 Dual-Quadrant Operation

In the dual-quadrant programmer-power supply system, as illustrated in Figure 1-3, an energy absorber is added which allows the magnetic energy to be converted to thermal energy, thereby allowing much faster magnetic field reduction. This represents operation in quadrants 1 and 4 of Figure 1-1. The disadvantage to this type of system is that whenever there is current flowing in the magnet, there is energy being dissipated in the energy absorbing element, which is sometimes a significant portion of the power required to operate the system.

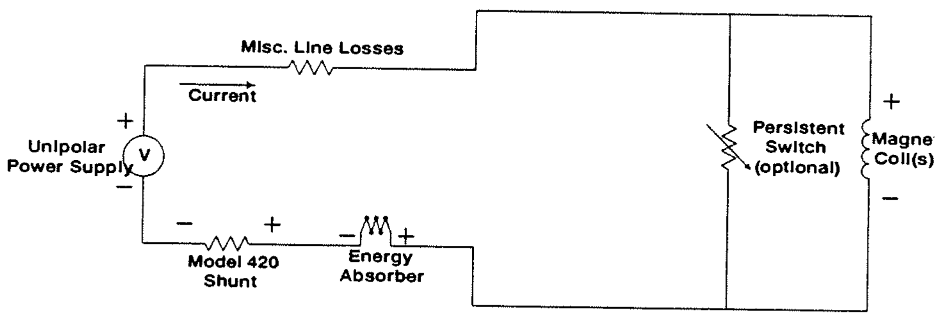


Figure 1-3. Dual-Quadrant Magnet System

1.5.3 Simulated Four-Quadrant Operation

In the simulated four-quadrant programmer-power supply system, as show in Figure 1-4, a mechanical current reversing switch is included, usually in the energy absorber. This allows the current in the magnet to be

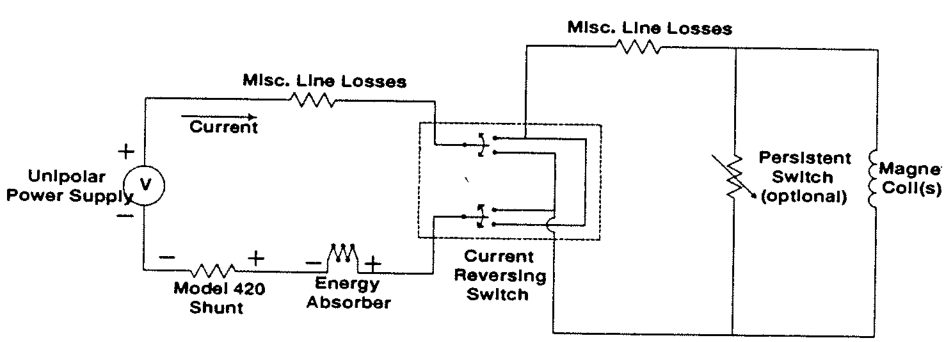


Figure 1-4. Simulated Four-Quadrant Magnet System

reversed after the current has first been reduced to zero. These systems usually incorporate some type of electronic interlock to ensure large amounts of current are not interrupted when the reversing sequence is initiated. The disadvantages of this system are energy inefficiencies and the finite period of time required to pause at zero magnet current before reversing the contacts and resuming magnet energization. This pause precludes smooth magnetic field reversals.

1.5.4 True Four-Quadrant Operation

The true four-quadrant magnet power supply system illustrated in Figure 1-5 offers the most control of all the modes of operation. Efficiency is increased and reversible magnetic field profiles are attainable without discontinuities. All of the current switching is performed electronically so that system reliability is improved. Disadvantages of the four-quadrant system include the increased cost of the power supply if smooth, continuous field polarity reversal is not a requirement, and added complexity in protecting the power supply in the event of AC power loss or quenches.

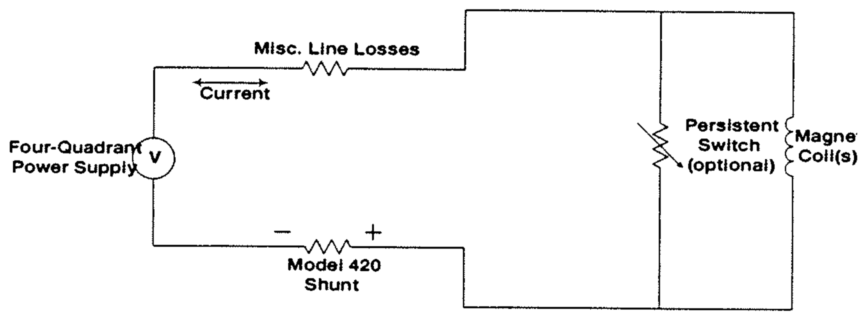


Figure 1-5. True Four-Quadrant System

2 Installation

Warning

Before energizing the instrument, the earth ground of the power receptacle must be verified to be at earth potential and able to carry the rated current of the power circuit. Using extension cords should be avoided, however, if one must be used, ensure the ground conductor is intact and capable of carrying the rated current.

In the event that the ground path of the instrument becomes less than sufficient to carry the rated current of the power circuit, the instrument should be disconnected from power, labeled as unsafe, and removed from place of operation.

Do not operate this instrument in the presence of flammable gases. Doing so could result in a life-threatening explosion.

Do not modify this instrument in any way. If component replacement is required, return the instrument to AMI facilities as described in the Troubleshooting section of this manual.

If this instrument is used in a manner not specified in this manual, the protection provided by the design, manufacture and documentation of the instrument may be impaired.

2.1 Inspecting and Unpacking

Carefully remove the instrument, interconnecting cabling and manual from the shipping carton and remove all packaging material. A rack mounting kit is supplied if the instrument was purchased with the rack mount option.

Note

If there is any shipping damage, save all packing material and contact the shipping representative to file a damage claim. Do not return the instrument to AMI unless prior authorization has been received.

2.2 Model 420 Mounting

If the instrument is to be used as a table top model, place the instrument on a flat, secure surface. The Model 420 uses an internal fan for forced-air cooling. Allow at least 1/8" spacing beneath the unit for proper ventilation.

Warning

Do not remove the cabinet feet and then reinsert the original screws. Doing so could present a severe life-threatening electrical hazard. If removal of the cabinet feet is desired, omit replacing the screws or replace the original screws with screws not to exceed 1/4" in length.

If the instrument is to be rack mounted, follow the following steps:

1. Attach the rack mount adapter pieces to the instrument by first removing the four screws on the side of the instrument that attach the cover to the chassis. Attach the rack mount adapter pieces to the sides of the instrument by reinstalling the screws.
2. Install the Model 420 in a 19" wide instrument rack by securing the front panel to the rail in each of the four corners with mounting hardware supplied by the cabinet manufacturer.

2.3 Power Requirements

Warning

The Model 420 operates on 50-60 Hz power and may be configured for 100-120 or 200-240 VAC. The power requirement for each instrument is marked on the rear panel of the instrument adjacent to the power entry module. Be sure your instrument is configured for your power source prior to plugging in the line cord. Do not fail to connect the input ground terminal securely to an external earth ground.

Ensure the front panel power switch is in the OFF (**O**) position. Verify that the instrument is configured for the proper operating voltage by referring to the label adjacent to the power entry module on the rear panel of the instrument. If the operating voltage is correct, plug the line cord into the appropriate power receptacle.

If the instrument operating voltage needs to be changed, ensure the instrument is de-energized by disconnecting the power cord from the power source. Remove the instrument cover by removing the four button head capscrews on both sides of the cover (3/32" allen driver required) and the four button head capscrews from the corners of the cover on the back panel (5/64" allen driver required) and slide the voltage selector switch on the main printed circuit board to the proper voltage. Replace the instrument cover.

Note

The voltage selector switch is labeled "115" for nominal line voltages from 100 to 120 VAC. The switch is labeled "230" for nominal line voltages of 200 to 240 VAC.

2.4 Collecting Necessary Information

In order to properly configure the Model 420, certain system information is required. Such parameters as the magnet physical properties, type of power supply, persistent switch heating current requirements, and voltage and current constraints of the magnet are entered into the instrument once and the battery-backed memory will retain the data even after power is removed from the instrument. An example of the data to be entered and how it is entered is described in paragraph 3.2.5 on page 48.

If the Model 420 was purchased as part of a magnet system, essential data has already been entered at the AMI factory and a configuration sheet should be provided detailing the settings.

2.5 System Interconnects

The following diagrams will assist the user in system equipment setup. If the Model 420 was purchased as part of a magnet system, all applicable system components and wiring harnesses will be shipped with the system. Since many different configurations are possible, use the system interconnection diagram that most closely corresponds with your system; this is usually denoted by the operating characteristics of the power supply.

For maximum immunity to AC line noise, ensure that the chassis of the Model 420 has a direct, low impedance electrical connection to the chassis of the power supply to which the **PROGRAM OUT** is connected. The connection can be made via a grounding strap, or if rack mounted, through the rack itself if it is constructed of electrically-conductive material.

> **Caution**
>
> *The wiring between the power supply and the vapor-cooled current leads must be of sufficient size to carry the full rated current of the power supply. Typically, for short runs (less than 25 ft (7.6 m)) for 100 amperes 4 AWG wire is sufficient and for 200 amperes, 2 AWG is sufficient.*

Note that an AMI Model 13x Liquid Helium Level Instrument is shown as a possible component of each system. The main instrumentation cable connecting the magnet support stand and the Model 420 Magnet Station Connector J7A and J7B contains all the instrumentation and control connections needed to control and monitor the magnet. The signals in this cable which are required to monitor LHe level and temperatures are also presented at the LHe Level / Temp connectors J8A and J8B. Refer to the *Appendix* for pin-outs of these and other connectors.

2.5.1 Unipolar Supply without Energy Absorber

When the Model 420 is used in the single quadrant mode, the magnet power supply system consists of the Model 420, a unipolar power supply (typically an AMI Model 12100PS or 12200PS) and associated interconnecting cabling. The diagram of Figure 2-1 shows this system. Connect the cabling in the following manner:

a. Connect the positive (POS) power supply lead (1) to the positive vapor-cooled current lead (2) using 1/4-20 or similar hardware.

   Note

   The use of locking hardware is recommended for all high current connections.

   Warning

   Ensure the protective diode remains installed across the output terminals of the power supply with the anode at the **NEG***ative terminal and the cathode at the* **POS***itive terminal. Removal of this protective diode may cause serious injury to personnel and damage to the power supply under certain loss of power conditions.*

b. Connect the negative vapor-cooled current lead (3) to the positive (+) shunt terminal (4) on the back of the Model 420.

c. Connect the negative (–) shunt terminal (5) on the back of the Model 420 to the negative (NEG) power supply lead (6).

d. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the BNC connector attached to the terminal strip on the rear of the power supply (7).

e. Install an instrumentation cable between the magnet support stand top plate connector (8) and the magnet station connector J7A or J7B.

f. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x Liquid Helium Level Instrument and/or temperature instrument (9).

g. Remote communications via IEEE-488 and/or RS-232 (or optional RS-422) can be accomplished by connecting suitable cabling to J11 and/or J12, respectively.

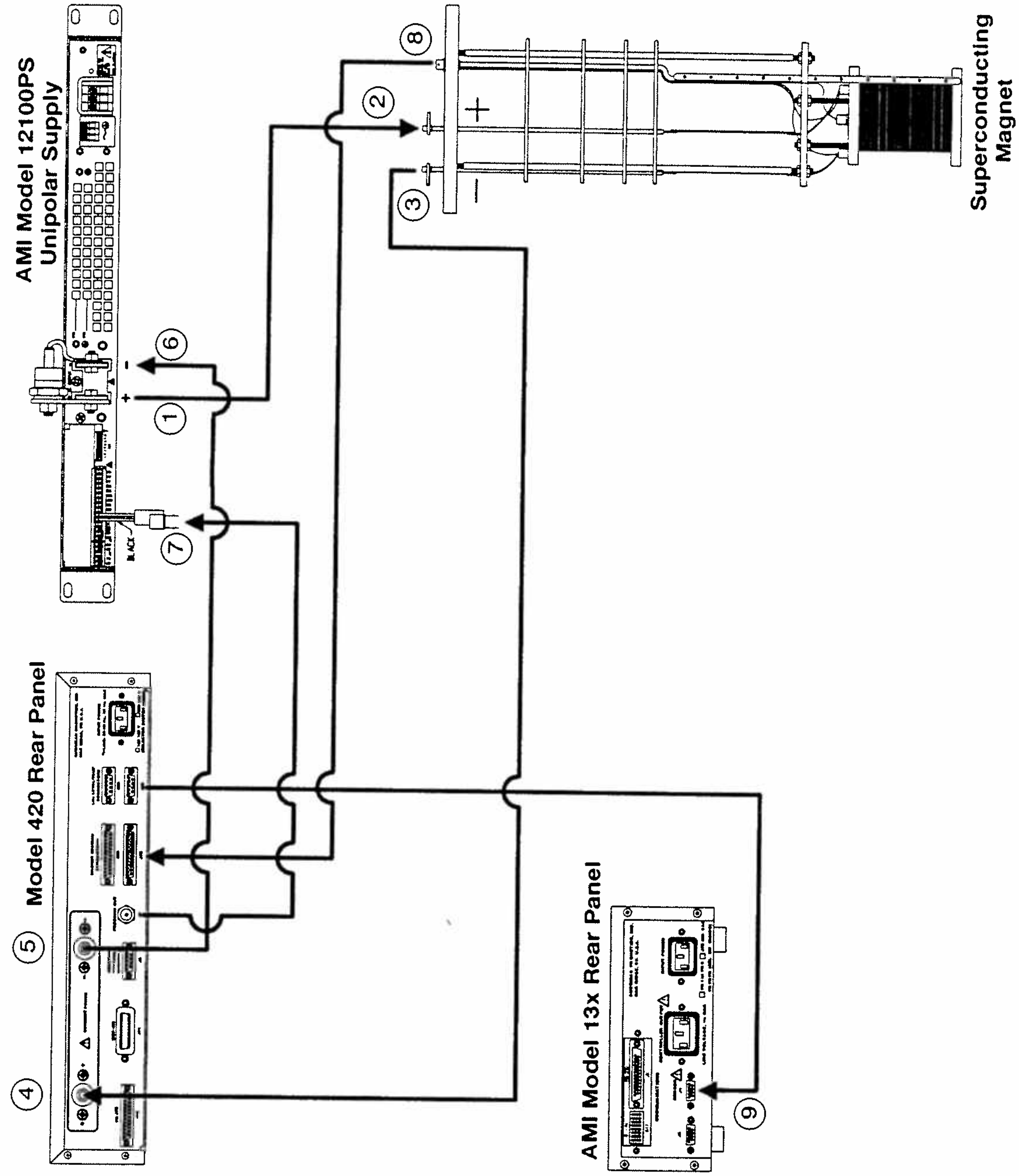


Figure 2-1. System interconnect diagram for a unipolar supply without an energy absorber.

2.5.2 Unipolar Supply with AMI Model 601 Energy Absorber

If the Model 420 is to be used in the dual quadrant mode, the magnet power supply system consists of the Model 420, a unipolar power supply (typically an AMI Model 12100PS or 12200PS), an AMI Model 601 Energy Absorber, and associated interconnecting cabling. Figure 2-2 depicts the Model 12100PS power supply used in conjunction with the Model 601 Energy Absorber and ancillary components.

Connect the cabling in the following manner:

a. Connect the positive (POS) output terminal (1) of the power supply to the positive (+) terminal (2) of the Model 601 Energy Absorber using 1/4-20 or similar hardware.

Note

The use of locking hardware is recommended for all high current connections.

Warning

Ensure the protective diode remains installed across the output terminals of the power supply with the anode at the **NEG***ative terminal and the cathode at the* **POS***itive terminal. Removal of this protective diode may cause serious injury to personnel and damage to the power supply under certain loss of power conditions.*

b. Connect the negative (–) terminal (3) of the Model 601 Energy Absorber to the positive (+) vapor-cooled current lead (4).

c. Connect the negative (–) vapor-cooled current lead (5) to the positive (+) shunt terminal (6) on the back of the Model 420.

d. Connect the negative (–) shunt terminal (7) of the Model 420 to the negative (NEG) output lug of the power supply (8).

e. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the BNC connector attached to the terminal strip on the rear of the power supply (9).

f. Install an instrumentation cable between the magnet support stand top plate connector (10) and the magnet station connector J7A or J7B on the rear of the Model 420.

g. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x

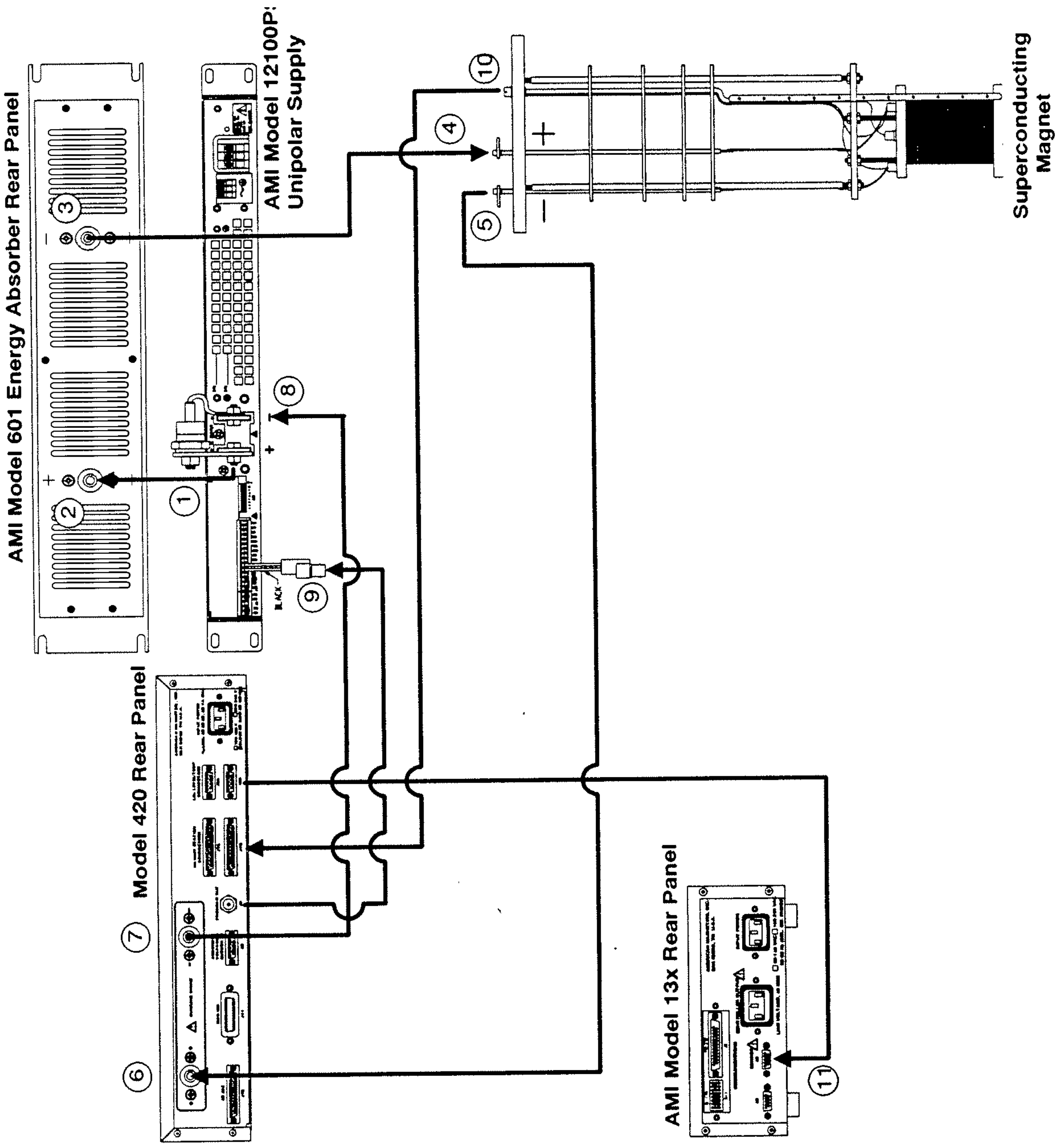


Figure 2-2. System interconnect diagram for a unipolar supply with an AMI Model 601 Energy Absorber.

Liquid Helium Level Instrument and/or temperature instrument (11).

h. Remote communications via IEEE-488 and/or RS-232 (or optional RS-422) can be accomplished by connecting suitable cabling to J11 and/or J12, respectively.

2.5.3 Unipolar Supply with AMI Model 600/620 Energy Absorber

When the Model 420 is used in the dual quadrant mode with *legacy AMI hardware*, the magnet power supply system consists of the Model 420, a unipolar power supply (typically an AMI Model 10100 or 10200), an energy absorber (an AMI Model 600 for 100 ampere applications or Model 620 for 200 ampere applications) and associated interconnecting cabling. Figure 2-2 depicts the Model 10100 power supply used in conjunction with the Model 600 Energy Absorber and ancillary components.

Connect the cabling in the following manner:

a. Connect the positive (POS) output terminal (1) of the power supply to the positive (+) input cable (2) of the Energy Absorber using 1/4-20 or similar hardware.

Note

The use of locking hardware is recommended for all high current connections.

Warning

Ensure the protective diode remains installed across the output terminals of the power supply with the anode at the **NEG***ative terminal and the cathode at the* **POS***itive terminal. Removal of this protective diode may cause serious injury to personnel and damage to the power supply under certain loss of power conditions.*

b. Connect the negative (–) input cable (3) of the Energy Absorber to the positive (+) shunt terminal (4) of the Model 420.

c. Connect the negative (–) shunt terminal (5) of the Model 420 to the negative (NEG) output lug of the power supply (6).

d. Connect the positive (+) output cable (7) of the Energy Absorber to the positive (+) vapor-cooled current lead (8).

e. Connect the negative (–) vapor-cooled current lead (9) to the negative (–) output cable (10) of the Energy Absorber.

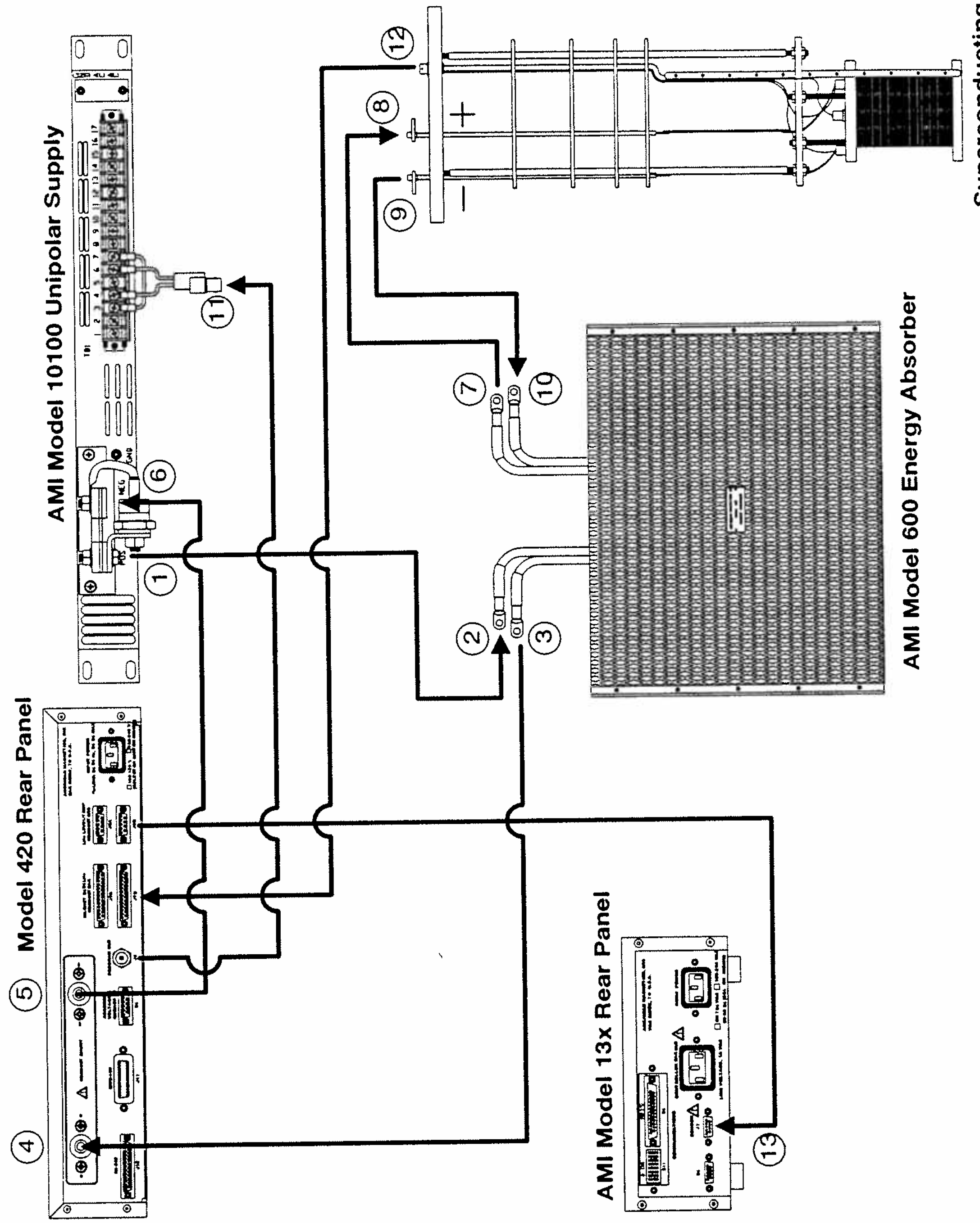


*Figure2-3.S*ystem interconnect diagram for a unipolar supply with an AMI Model 600/620 Energy Absorber.

f. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the BNC connector attached to the terminal strip on the rear of the power supply (11).

g. Install an instrumentation cable between the magnet support stand top plate connector (12) and the magnet station connector J7A or J7B on the rear of the Model 420.

h. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x Liquid Helium Level Instrument and/or temperature instrument (13).

i. Remote communications via IEEE-488 and/or RS-232 (or optional RS-422) can be accomplished by connecting suitable cabling to J11 and/or J12, respectively.

2.5.4 Unipolar Supply with AMI Model 610/630 Energy Absorber and Current Reversing Switch

For a simulated four quadrant power supply system with *legacy AMI hardware*, the components include the Model 420, a unipolar power supply (typically an AMI Model 10100 or 10200), an energy absorber / reversing switch (an AMI Model 610 for 100 ampere applications or Model 630 for 200 ampere applications) and associated interconnecting cabling. Figure 2-4 depicts the Model 10100 power supply used in conjunction with the Model 610 Energy Absorber / Reversing Switch and ancillary components.

Connect the cabling in the following manner:

a. Connect the positive (POS) output terminal (1) of the power supply to the positive (+) input cable (2) of the Energy Absorber / Reversing Switch using 1/4-20 or similar hardware.

Note

The use of locking hardware is recommended for all high current connections.

Warning

Ensure the protective diode remains installed across the output terminals of the power supply with the anode at the **NEG***ative terminal and the cathode at the* **POS***itive terminal. Removal of this protective diode may cause serious injury to personnel and damage to the power supply under certain loss of power conditions.*

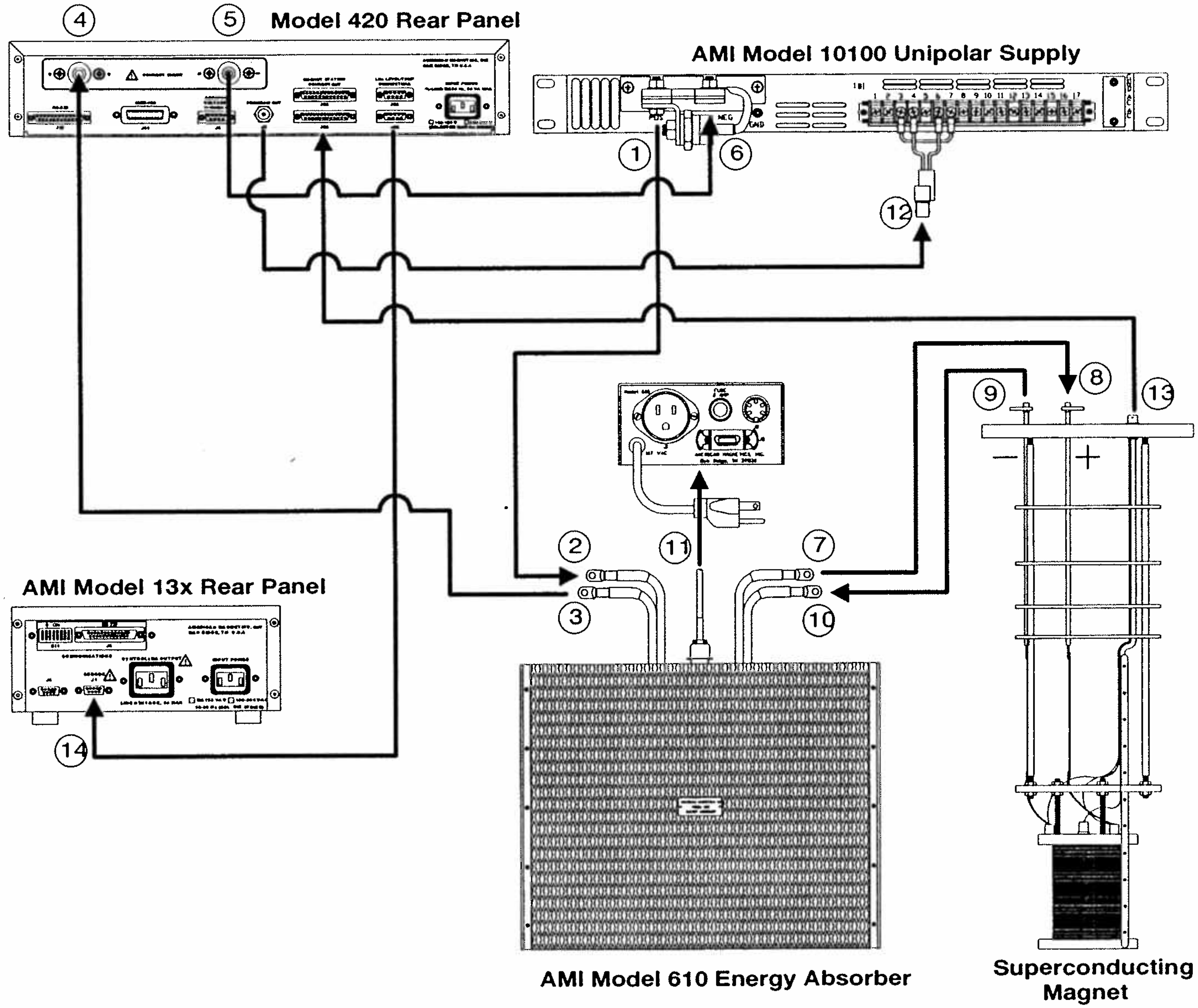


Figure 2-4. System interconnect diagram for a unipolar supply with an AMI Model 610/630 energy absorber and a current reversing switch.

b. Connect the negative (–) input cable (3) of the Energy Absorber to the positive (+) shunt terminal (4) of the Model 420.

c. Connect the negative (–) shunt terminal (5) of the Model 420 to the negative (–) output lug of the power supply (6).

d. Connect the positive (+) output cable (7) of the Energy Absorber / Reversing Switch to the positive (+) vapor-cooled current lead (8).

e. Connect the negative (–) vapor-cooled current lead (9) to the negative (–) output cable (10) of the Energy Absorber / Reversing Switch.

f. Connect the power and control cables (11) between the control unit and the Energy Absorber / Reversing Switch.

g. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the BNC connector attached to the terminal strip on the rear of the power supply (12).

h. Install an instrumentation cable between the magnet support stand top plate connector (13) and the magnet station connector J7A or J7B.

i. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x Liquid Helium Level Instrument and/or temperature instrument (14).

j. Remote communications via IEEE-488 and/or RS-232 (or optional RS-422) can be accomplished by connecting suitable cabling to J11 and/or J12, respectively.

2.5.5 High-Current Four-Quadrant Supply

For a true four quadrant power supply system, the components include Model 420, a four quadrant power supply (typically an AMI Model 4Q05100PS), and associated interconnecting cabling. Figure 2-5 illustrates the interconnects for an AMI Model 4Q05100PS power supply.

Connect the cabling in the following manner:

a. Connect the positive (+) power supply terminal (1) to the positive vapor-cooled current lead (2) using 1/4-20 or similar hardware.

Note

The use of locking hardware is recommended for all high current connections.

b. Connect the negative vapor-cooled current lead (3) to the positive (+) shunt terminal (4) on the back of the Model 420.

c. Connect the negative (–) shunt terminal (5) on the back of the Model 420 to the negative (–) power supply terminal (6).

d. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the **PROGRAM IN** connector (7) on the rear of the power supply.

e. Install an instrumentation cable between the magnet support stand top plate connector (8) and the magnet station connector J7A or J7B.

f. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x Liquid Helium Level Instrument and/or temperature instrument (9).

g. Remote communications via IEEE-488 and/or RS-232 (or optional RS-422) can be accomplished by connecting suitable cabling to J11 and/or J12, respectively.

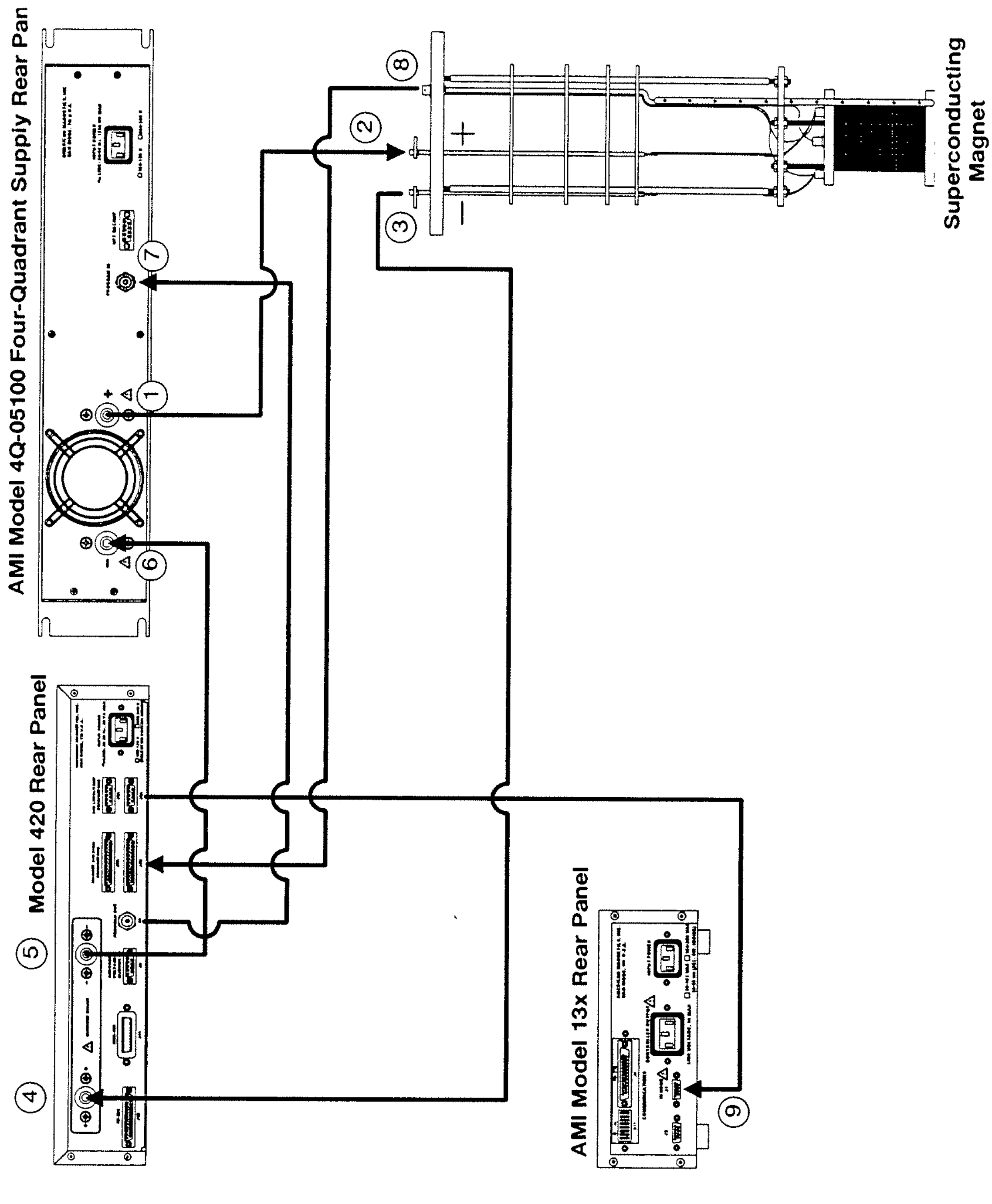


Figure 2-5. System interconnect diagram for the AMI Model 4Q-05100 power supply.

2.5.6 Low-Current, High-Resolution Four-Quadrant Supply

AMI offers a low-current (5 A or 10 A maximum) system option to achieve high-resolution control of the magnet current. The system consists of a Model 420, a low-current four-quadrant power supply (typically the Kepco BOP series), and associated interconnecting cabling. Figure 2-6 illustrates the interconnects for a Kepco BOP 20-5M or 20-10M power supply.

> **Note**
>
> *Due to continuous discharge voltage limitations present in the Kepco BOP series supplies, the charging / discharging voltage is limited to a maximum of 10 volts by the Model 420 for maximum safety.*

Connect the cabling in the following manner:

a. Connect the positive (+) power supply terminal (1) to the positive vapor-cooled current lead (2) using 1/4-20 or similar hardware.

b. Connect the negative vapor-cooled current lead (3) to the positive (+) shunt terminal (4) on the back of the Model 420.

c. Connect the negative (–) shunt terminal (5) on the back of the Model 420 to the negative (–) power supply terminal (6).

d. Connect the coaxial cable from the **PROGRAM OUT** connector on the back of the Model 420 to the **VOLTAGE PROGRAMMING INPUT** connector (7) on the front panel of the power supply. Note the cable configuration as shown in the diagram.

e. Install an instrumentation cable between the magnet support stand top plate connector (8) and the magnet station connector J7A or J7B.

f. Install an instrumentation cable between the LHe/Temp connectors J8A and/or J8B on the rear of the Model 420 and the Model 13x Liquid Helium Level Instrument and/or temperature instrument (9).

g. Set the Kepco power supply **MODE** to voltage control (to the left), and set both manual control switches to the **OFF** position.

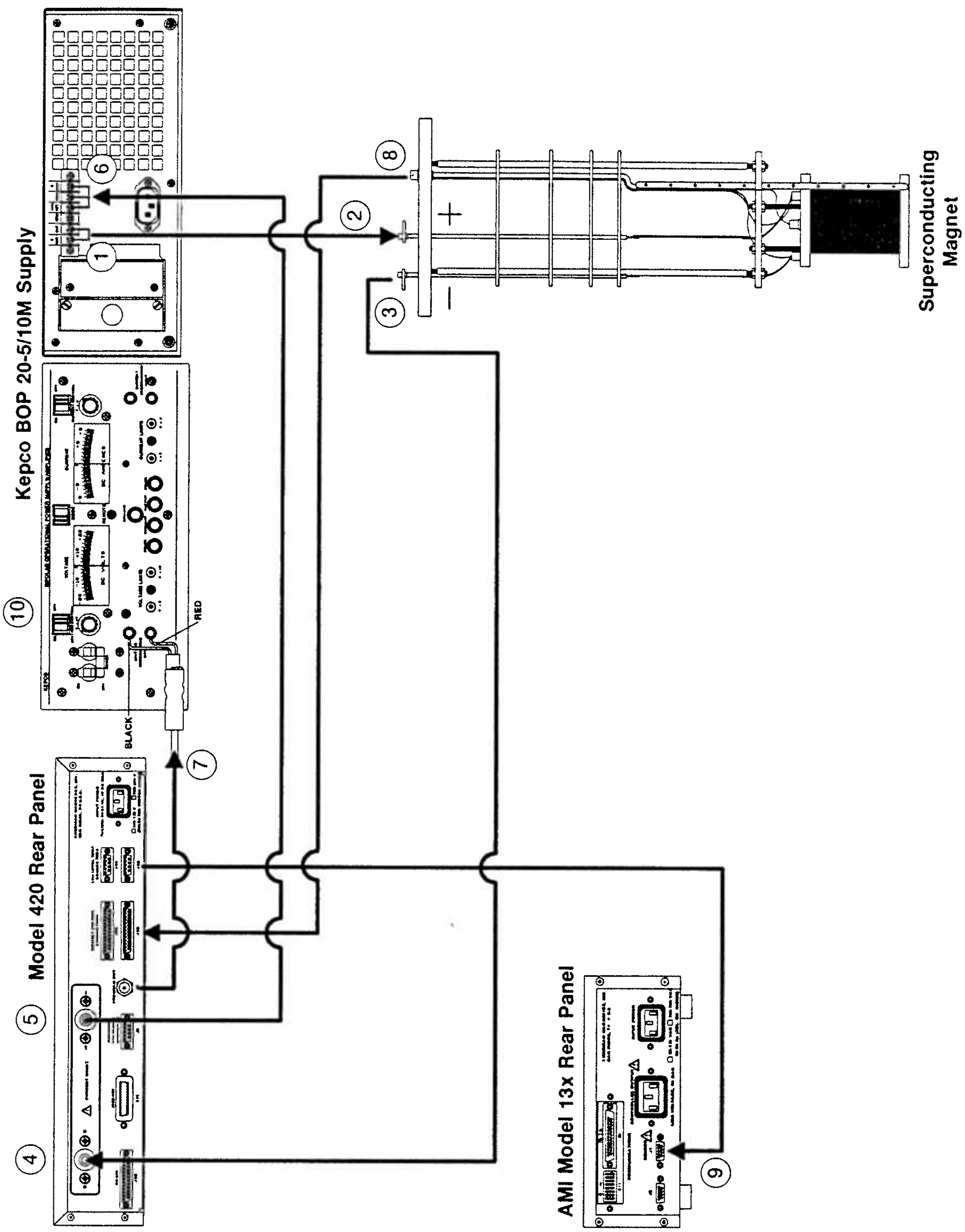


Figure 2-6. System interconnect diagram for the Kepco BOP series power supply.

2.5.7 Third-Party Power Supplies

The Model 420 has been designed to function with a wide variety of third-party power supplies. Please contact an AMI Technical Support Representative for compatibility with specific models. Custom modifications can be made to accommodate supplies that are not compatible with the standard Model 420 configurations.

2.6 Special Configurations

The Model 420 has been designed for optimal operation with a superconducting magnet (i.e. a very low resistance, high inductive load) with a persistent switch. The Model 420 is capable of operating other loads, however, some modification to the instrument settings and/or connections must be considered. Two commonly encountered configurations are 1) superconducting magnets without a persistent switch, and 2) operation on a short-circuit or resistive load.

2.6.1 Superconducting Magnets without a Persistent Switch

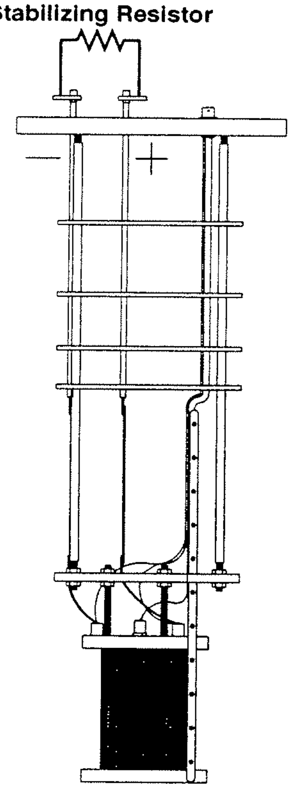


Figure 2-7. Illustration of stabilizing resistor in parallel with the magnet.

For superconducting magnets without a persistent switch, the Model 420 *requires* the addition of an external stabilizing resistor in parallel with the magnet per Figure 2-7. If the stabilizing resistor is omitted, *the system current will oscillate* when attempting to charge the magnet.

The general guidelines recommended by AMI for selecting the resistor value and estimating the power handling requirement are as follows:

$$R \leq 2\pi L$$

$$P = \frac{(V_L)^2}{R}$$

where R is the required resistance in ohms, L is the magnet inductance in Henries, V_L is the voltage limit setting of the Model 420 in volts, and P is the required power rating of the resistor in Watts. For best results, R should be chosen as close to the calculated value as is practical, typically within 25%, with a maximum value not exceeding 20 ohms.

2.6.2 Short-Circuit or Resistive Load

If operating with a short-circuit as a load *without the presence of a superconducting magnet*, the Model 420 must be manually configured for stability. Normally, when the persistent switch heater is deactivated, the Model 420 essentially sees a short-circuit as the load since the persistent switch shunts all current flow away from any connected magnet. Therefore, one method of operating a short-circuit is to indicate that a persistent switch is present with the persistent switch heater deactivated.

The preferred method is to indicate that a persistent switch is not present (see paragraph 3.2.2.4) and adjust the stability setting (see paragraph 3.2.2.1) to control the load. *A stability setting of 100% will always allow control of a short-circuit as the load*, regardless of the state of the persistent switch heater.

If the resistance of the load is *increased*, the stability setting must be *decreased* to improve the transient response of the system. If the current appears to lag, then decrease the stability setting until the system is responsive. If the current appears to oscillate, increase the stability setting until the oscillations are damped.

Note

If you have purchased a superconducting magnet with the Model 420, AMI will normally provide a recommended stability setting for optimal operation of the magnet system. If you operate the Model 420 with a different load, be sure to restore the stability setting to the recommended value when the superconducting magnet is reconnected.

The stability setting is essentially manual control of the gain of a integrator present in the control logic of the Model 420. Increasing the stability setting decreases the gain of the integrator.

A *special case* is the energy absorber designs available from AMI. For example, the Model 601 is an infinite-resistance device until 5 VDC is achieved across its terminals. Once the 5 VDC "bias" is present, the Model 601 allows current flow with a nominal 2 mΩ series resistance. Therefore, the Model 420 will require an "integration time" to overcome the 5 VDC bias. Once the bias is achieved, the series resistance is minimal and the Model 601 apears as a short-circuit. It is not possible to decrease the stability setting to remove the integration time, since once the 5 VDC bias is achieved, the load is a short-circuit and the system will become unstable.

Note that when operating with a superconducting magnet in the circuit, the integration gain of the Model 420 will be adequate to quickly "bias" the Model 601 and achieve a proper current ramping profile.

2.7 Power-Up and Test Procedure

It is important to verify that the magnet system has been properly connected before the superconducting magnet is energized. This is especially recommended if the system is to be controlled via a computer since this setup will allow software debugging without the potential for damage to the magnet. The following procedures will assist the user in the verifying key system components.

1. Using the appropriate diagram from section 2.5 as a guide, verify all system components are connected as shown. If there is any doubt as to the correct connection of a component, contact an AMI Technical Support Representative. The user is required to properly make a few connections between the various system components which were disconnected to facilitate packing and shipping.

2. Temporarily place a short across the magnet current terminals. This may be most easily accomplished by unfastening the heavy cables from the vapor-cooled current leads and fastening them together. This will allow rudimentary power supply checks without energizing the superconducting magnet.

3. Energize the Model 420 by placing the power switch in the **I** (ON) position.

4. Enter a stability setting of 100% in the *Load* setup menu. Refer to paragraph 3.2.2.1 on page 42 for more information.

5. Energize the power supply.

   <u>Note</u>

   Also energize the Model 601/610/630 energy absorber unit if applicable.

6. Verify the various setup menu values for your system (with the exception of the stability setting). If the Model 420 was purchased with an AMI magnet, AMI has preset the setup menu values for proper operation. See paragraph 3.2.5 on page 48 for more discussion of the setup menu values.

7. Set the ramp rate to 1 A/sec. Refer to paragraph 3.3.1.2 on page 52.

8. Set the programmed current to 10 A. Refer to paragraph 3.3.3 on page 53.

9. Initiate ramping to the programmed current by pressing the **RAMP/ PAUSE** switch (LED indicator on button should extinguish).

10. The system should ramp to 10 amperes in approximately 10 seconds. Verify this is the case.

 Note

 If an energy absorber unit is connected, the Model 420 may take significantly longer to ramp the current to 10 A. The Model 420 must first develop a supply output voltage to overcome the forward voltage drop of a connected energy absorber. During actual magnet operation, the presence of an energy absorber will not significantly delay the ramping operation since the Model 420 control gain is increased by orders of magnitude when an inductive load is connected.

11. When the programmed current is achieved, the Current/Field Limit LED adjacent to the **PROGRAMMED CURRENT/FIELD** switch will be illuminated. The display should show "**+ 10.00 A** –" indicating that the Model 420 is in the holding mode at the programmed current value.

 Note

 There may be a discrepancy between the current shown on the power supply display and the current displayed on the Model 420. The shunt measurement system incorporated in the Model 420 is normally more accurate than the power supply shunt. The Model 420 is calibrated to 0.1% of the actual current, which is typically five times more accurate than most integrated power supply shunts.

12. Verify that the output current display of the power supply indicates that it is supplying 10 amperes to the load (which is only the cabling in this case).

13. Set the programmed current to the current limit value. Refer to paragraph 3.2.2.3 on page 43 to determine the current limit value. After the new programmed current value is entered, the Model 420 should ramp automatically to the new setting.

14. When the new programmed current value is reached, the power supply current display should also indicate the new value.

15. Press the **RESET/ZERO** button to ramp the system to zero current (LED indicator on button should energize).

16. Perform remote control software checkout as required.

17. Turn off the power supply.

18. Reset the stability setting and ramp rate of the Model 420 to an appropriate value for the magnet to be operated. Then turn off the Model 420.

19. Remove the short from the power supply leads and connect the leads to the vapor-cooled current leads of the magnet.

After successful completion of this test of the Model 420 and power supply system, the system is ready for operation with a superconducting magnet. Refer to the ramping function example presented on page 54 for a discussion of the various available ramping methods.

3 Operation

This section describes each display and operating mode of the Model 420 instrument and the related functions. Every available menu is illustrated and described in detail. An example setup of the instrument is presented in paragraph 3.2.5 on page page 48. An example ramping operation is presented in paragraph 3.3.6 on page 54.

3.1 Default Display Modes

The default display modes are illustrated in the diagram below. There are four default display modes which can be cycled by repeatedly pressing the **OPTION** key when not within the setup menu or a setup submenu. The operating values on the left side of the display are always visible during any mode of operation or menu selections.

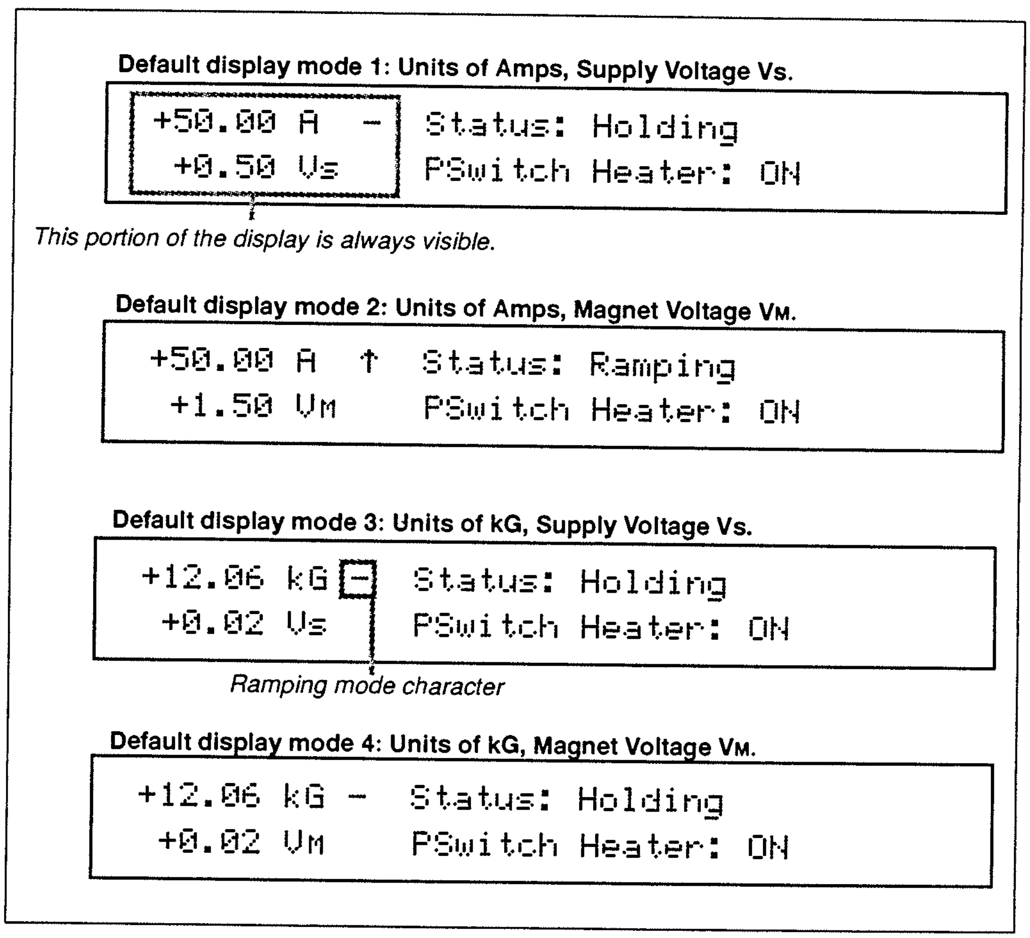


Figure 3-1. Default display modes.

The operating (shunt) current is displayed in Amperes and may alternately be displayed as *estimated field* in kilogauss (or Tesla) in display mode 3 or 4 if a coil constant has been specified in the setup (see paragraph 3.2.2.2). V_S indicates the commanded output voltage of the power supply in volts. V_M indicates the voltage measured across the terminals of the connected superconducting magnet.

Table 3-1. Description of ramping mode characters.

P	Paused[a]
↑	Ramping Up
↓	Ramping Down
–	Holding
°	Heating Persistent Switch

a. Displayed in reverse video.

The ramping mode character is always visible (except during a quench condition) and is displayed just to the right of the operating current or field display. The ramping mode character may be one of five states as shown in Table 3-1.

If the ramping mode character is blank, then a quench condition exists. See paragraph 3.3 for a detailed discussion of the meaning of the ramping modes.

3.1.1 Entering Numerical Values

A consistent method of entering values is used within menus requiring numerical entries. Once a menu is selected, the user starts an entry by pressing a digit, the decimal key, or the sign (**+/-**) key. The display will begin a new entry and display a cursor _ as a prompt for the next digit or decimal entry. Once entry is initiated, the display will show an asterisk * indicating that entry is in progress. To accept the entered value, press the **ENTER** key. Values are *not* applied to the operation of the instrument until the **ENTER** key is pressed and the asterisk disappears from the display. An example of an entry in progress is illustrated below:

```
+50.00 A  -  Programmed Current (A)*
 +0.50 Vs    +74_
```

If the **ESC** key is pressed *once* while entry is initiated, the entered digits will be cleared and the cursor will remain for reentry of a new desired value. If the **ESC** key is depressed *twice*, the setting will revert to the previous value and the entry is cancelled.

3.1.2 Menu Option Selection

Some menus may require the user to cycle through and select from a list of predefined options. Such menus will display a cursor ▶ which indicates that a list of predefined options are available from which to select. Pressing the **OPTION** key moves the cursor forward within the list. The value to which the cursor points is the specified setting and is effective *immediately* upon selection (i.e. the **ENTER** key is not required).

3.1.3 Exiting Menus

Menus are exited by pressing the **ESC** key while no entry is in progress. The display will revert to a default display mode (see paragraph 3.1 above). If the menu is a submenu of the setup mode, then the display reverts to the setup mode selection screen described in paragraph 3.2 below.

3.2 Setup Menu Descriptions

The setup menu is entered by pressing the **SETUP** key. This will initiate the following initial setup menu display:

```
+50.00 A   -  Setup Mode (Select one)
 +0.50 Vs    ▶Supply  Load  Misc  Comm
```

A cursor ▶ displayed to the left of a menu item indicates which setup submenu item will become active when the **SETUP** key is again pressed. The cursor can be moved to the next menu item by pressing the **OPTION** key. The setup menu may be exited by pressing the **ESC** key once.

Once the **SETUP** key is pressed and a *submenu* is entered, the user will be able to access several additional parameters illustrated in Figure 3-2 on the following page. Attempts to set a parameter within a submenu to a value outside of the valid range are ignored and, if attempted, the instrument will beep once indicating an error and revert to the previous setting. The **OPTION** key is used to select from a list of options. The dial may also be used to make incremental adjustments to parameters requiring a numerical input (or where indicated with a menu selection). Move to the next parameter within a submenu by pressing the **SETUP** key. Submenus may be exited to the initial setup menu by pressing **ESC** once.

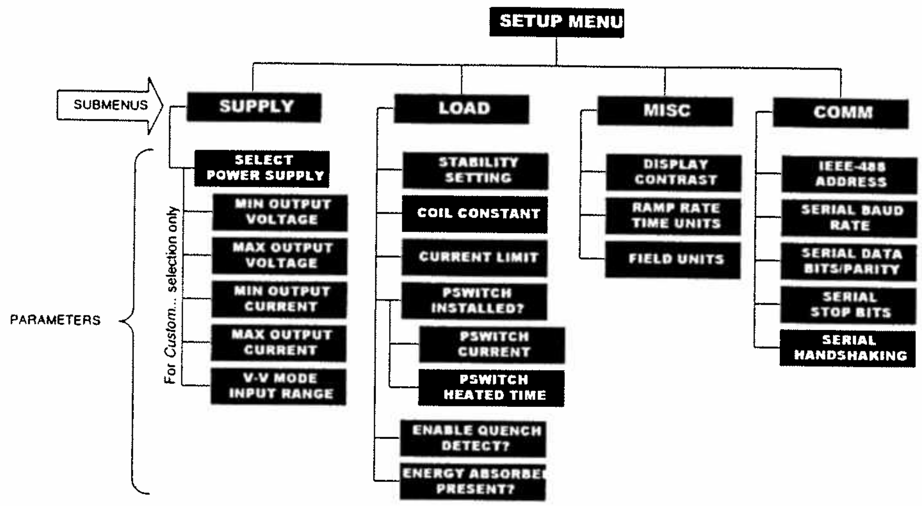


Figure 3-2. Setup menu, submenus, and parameter diagram.

3.2.1 Supply Setup Submenu

The *Supply* setup submenu provides for the specification of the power supply parameters. If you wish to set the limits of operation for a connected magnet, refer to the current limit and the voltage limit configurations.

If using a standard power supply supported by AMI, selecting a power supply within the *Select Power Supply* menu sets all the remaining parameters in the supply menu according to Table 3-2.

3.2.1.1 Select Power Supply

```
+50.00 A   -  Select Power Supply
 +0.50 Vs     ▸AMI 12100PS
```

The select power supply parameter provides a selection menu that contains *presets for standard AMI power supplies.* Use the **OPTION** key to cycle through the list of selections. The selection becomes effective immediately. If a supply other than *Custom...* is selected, all remaining items within the *Supply* submenu are automatically set and cannot be edited. The available selections and associated supply parameters are provided in Table 3-2.

Table 3-2. Available *Select Power Supply* options.

Power Supply	Min Output Voltage (V)	Max Output Voltage (V)	Min Output Current (A)	Max Output Current (A)	V-V Mode Input Range (V)
AMI 12100PS	+0.000	+12.000	+0.000	+100.000	+0.000 to +10.000
AMI 12200PS	+0.000	+12.000	+0.000	+200.000	+0.000 to +10.000
AMI 4Q05100PS	-5.000	+5.000	-100.000	+100.000	-10.000 to +10.000
AMI 10100PS	+0.000	+10.000	+0.000	+100.000	+0.000 to +5.000
AMI 10200PS	+0.000	+10.000	+0.000	+200.000	+0.000 to +5.000
HP 6260B	+0.000	+10.000	+0.000	+100.000	+0.000 to +10.000
Kepco BOP 20-5M[a]	-10.000	+10.000	-5.000	+5.000	-10.000 to +10.000
Kepco BOP 20-10M	-10.000	+10.000	-10.000	+10.000	-10.000 to +10.000
Xantrex XFR 7.5-140	+0.000	+7.500	+0.000	+140.000	+0.000 to +10.000
Custom...[b]	-20.000	+20.000	-200.000	+200.000	-10.000 to +10.000

a. The Kepco supplies are limited to only 1/2 of the output voltage range since the supplies are only designed to safely dissipate 1/2 of the rated power output.
b. The values shown for the Custom... option are defaults. The user should enter the appropriate values within the respective submenus. Custom values, once entered, are saved between power-ups.

Note

The supply selection cannot be changed while operating a magnet. The operating current must be less than ***0.1 A*** *in order to change the supply selection. If attempted, the Model 420 will beep and ignore the keypress.*

The power supply settings define the V-I ranges for a specific supply. For example, V-I diagrams are presented in Figure 3-3 for the AMI 12100PS and AMI 4Q05100PS selections. The AMI 12100PS operates as a one-quadrant system without the addition of an energy absorber. With the addition of an energy absorber, the AMI 12100PS system can function as a two-quadrant supply. The AMI 4Q05100PS power supply operates as a four-quadrant power supply without the addition of an energy absorber.

The addition of an energy absorber to the system does not change the capabilities of the power supply (or the values entered for the supply). The addition of an energy absorber does, however, change the *system* operating ranges per the example of Figure 3-3.

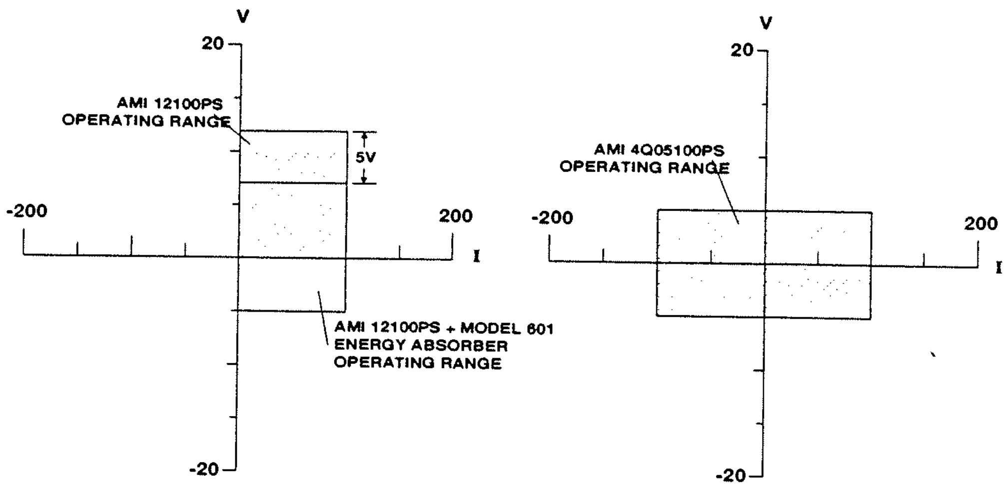


Figure 3-3. Example power supply operating ranges.

3.2.1.2 Min Output Voltage

```
+50.00 A   -   Min Output Voltage (V)
 +0.50 Vs      +0.000
```

The minimum output voltage is specified in volts and reflects the minimum compliance of a connected power supply. The valid range is 0.000 to -20.000 volts. A *unipolar* power supply has a minimum output voltage of 0.000 volts. This setting can be edited only if a *Custom...* supply is selected.

3.2.1.3 Max Output Voltage

```
+50.00 A   -   Max Output Voltage (V)
 +0.50 Vs      +12.000
```

The maximum output voltage is specified in volts and reflects the maximum compliance of a connected power supply. The valid range is 0.001 to +20.000 volts. This setting can be edited only if a *Custom...* supply is selected.

3.2.1.4 Min Output Current

```
+50.00 A   -   Min Output Current (A)
 +0.50 Vs      +0.000
```

The minimum output current is specified in Amperes and reflects the minimum output current capacity of a connected power supply.

The valid range is 0.000 to as much as -2000.000 Amperes.[1] A *unipolar* power supply has a minimum output current of 0.000 Amperes. This setting can be edited only if a *Custom...* supply is selected.

3.2.1.5 Max Output Current

```
+50.00 A    -   Max Output Current (A)
 +0.50 Vs        +100.000
```

The maximum output current is specified in Amperes and reflects the maximum output current capacity of a connected power supply. The valid range is 0.001 to as much as +2000.000 Amperes.[1] This setting can be edited only if a *Custom...* supply is selected.

3.2.1.6 V-V Mode Input Range

```
+50.00 A    -   V-V Mode Input Range (V)
 +0.50 Vs       ►+0.000 to +10.000
```

The voltage-to-voltage mode input range defines the remote programming voltage range required by the connected power supply. The remote program voltage is the output signal commanded by the Model 420 to drive the connected power supply. This setting can be edited only if a *Custom...* supply is selected.

This menu item provides four preset selections and does not allow numerical entry of a range. Use the **OPTION** key to cycle through the list of presets. The presets include:

Table 3-3. Predefined voltage-to-voltage mode input range ranges.

+0.000 to +5.000
+0.000 to +10.000
-5.000 to +5.000
-10.000 to +10.000

1. The minimum and maximum output currents are bounded by the specific Model 420 configuration purchased. See page 7 for the specifications for each configuration. The entered value cannot exceed the programmable limits.

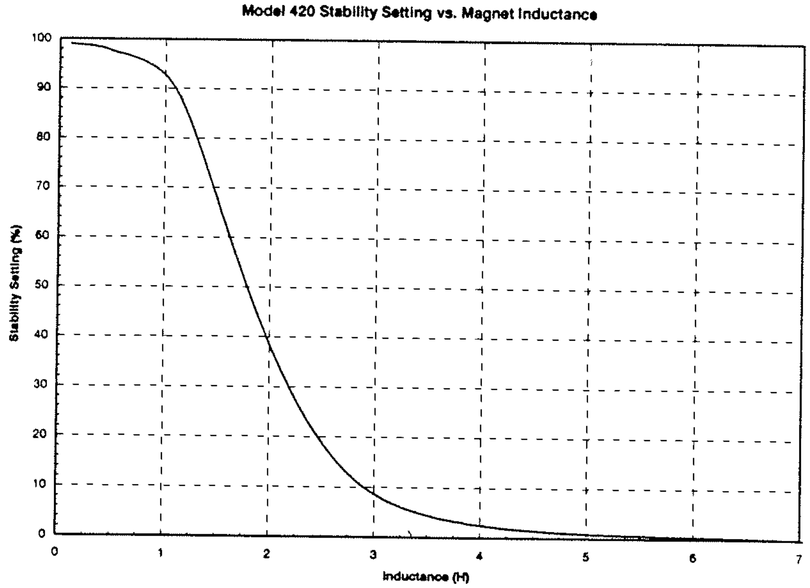
3.2.2 Load Setup Submenu

If the *Load* submenu is selected in setup, then several parameters associated with the superconducting magnet load can be viewed and/or specified by using the **SETUP** key to cycle through the available items.

3.2.2.1 Stability Setting

```
+50.00 A   -   Stability Setting (%)
 +0.50 Vs        0.0
```

The stability setting is specified in percent and controls the transient response and stability of the system. The valid range is from 0.0 to 100.0%. The default value is 0.0% unless preset by AMI. The chart below may be used to set the stability setting for magnets *with a persistent switch installed*. Magnets with an inductance of greater than 3 Henries that have a persistent switch installed should operate without problems with a stability setting of 0.0%.



3.2.2.2 Coil Constant

```
+50.00 A   -   Coil Constant (kG/A)
 +0.50 Vs        0.90000
```

The coil constant is a scaling factor which converts the operating current to kilogauss (10 kG = 1 Tesla). It is also often referred to as the *field-to-current ratio*. The coil constant is specified in kilogauss/ampere or Tesla/ampere. If the coil constant value is 0.0 kG/A (or

0.0 T/A), then the default display modes 3 and 4 are not available (see paragraph 3.1). The default value is 0.0 kG/A unless preset by AMI.

If the coil constant is not explicitly stated within the magnet specifications, the value can be obtained by dividing the rated field by the rated current.

3.2.2.3 Current Limit

```
+50.00 A   -  Current Limit (A)
 +0.50 Vs      +50.000
```

The current limit specifies the master current limit associated with a connected superconducting magnet. The limit *will always be observed* during any ramping mode. If the power supply is bipolar, then the current limit applies for both the positive and negative current direction.

The current limit and voltage limit (see page 51) define the safe operating region of the magnet within the operating range of the power supply as illustrated in Figure 3-4 below.

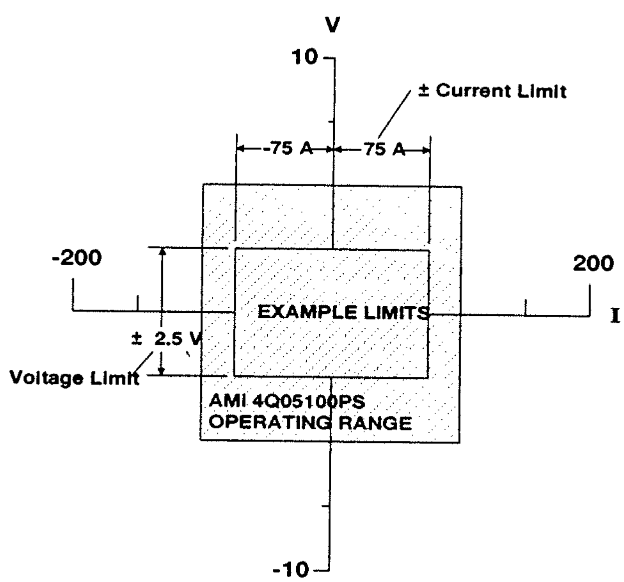


Figure 3-4. Example limits setup.

Note

The Voltage Limit can be directly accessed via the front panel **VOLTAGE LIMIT** *key.*

3.2.2.4 Persistent Switch Installed

```
+50.00 A  -  PSwitch Installed?
 +0.50 Vs      NO     ►YES
```

Indicates whether a persistent switch is installed. Use the **OPTION** key to cycle between *YES* and *NO*. If YES is selected, the persistent switch current and heating time for the switch must be specified. The default value is YES unless preset by AMI.

3.2.2.5 Persistent Switch Current

```
+50.00 A  -  PSwitch Current (mA)
 +0.50 Vs      10.0
```

The persistent switch current can be set from between 0.1 to 100.0 mA. The default value is 10.0 mA unless preset by AMI.

3.2.2.6 Persistent Switch Heated Time

```
+50.00 A  -  PSwitch Heated Time (sec)
 +0.50 Vs      15
```

The persistent switch heated time is the amount of time required for the persistent switch to completely heat and become resistive. The time may be set from 5 to 120 seconds. The default is 15 seconds unless preset by AMI.

During the persistent switch heating period, the Model 420 ramping functions are disabled. The time delay is necessary to ensure that the Model 420 will not switch to a higher gain required for proper magnet operation before the magnet is actually available in the circuit. If magnet operation is not stable after expiration of the heating period, increase the heating period to allow more time for the switch to heat. The default of 15 seconds is adequate for the majority of persistent switches.

3.2.2.7 Enable Quench Detect

```
+50.00 A  -  Enable Quench Detect?
 +0.50 Vs      NO     ►YES
```

The automatic quench detection function of the Model 420 may be enabled or disabled according to the preference of the operator. Use the **OPTION** key to cycle between *YES* and *NO*. The default value is YES.

A user input for *external quench detection* is provided on the rear panel of the instrument. The external input overrides the quench detection function of the Model 420 and cannot be disabled. For further discussion of the quench detection logic and operation, please refer to paragraph 3.5.

3.2.2.8 Energy Absorber Present

```
+50.00 A   -   Energy Absorber Present?
 +0.50 Vs      ►NO       YES
```

Indicates whether an energy absorber, such as the AMI Model 610, is connected to the system. Use the **OPTION** key to cycle between *YES* and *NO*. The default value is NO.

It is important for this setting to be correct since the internal gain tables of the Model 420 compensate for the additional load of the energy absorber if present. The increased gain when an energy absorber is present will decrease (but not eliminate) the time required for the system to "forward bias" the energy absorber.

3.2.3 Misc Setup Submenu

The *Misc* submenu allows specification of the display contrast setting, the ramp rate time units, and the field units.

3.2.3.1 Display Contrast

```
+50.00 A  -  Display Contrast (%)
 +0.50 Vs      80
```

Adjusts the contrast of the liquid crystal display from 0 to 100%. The default setting is 80%. Enter a value or use the dial to adjust the value.

3.2.3.2 Ramp Rate Time Units

```
+50.00 A  -  Specify Ramp Rate In?
 +0.50 Vs    ►Seconds     Minutes
```

Specifies whether ramp rate is specified and displayed in time units of seconds or minutes. Use the **OPTION** key to cycle between selections. The selected option also applies to the appropriate remote interface commands. The default setting is seconds.

3.2.3.3 Field Units

```
+50.00 A  -  Field Units
 +0.50 Vs    ►Kilogauss    Tesla
```

Specifies whether the field is specified and displayed in units of kilogauss (kG) or Tesla (T). Use the **OPTION** key to cycle between selections. The selected option also applies to the appropriate remote interface commands. The default setting is kilogauss.

3.2.4 Comm Setup Submenu

The *Comm* submenu allows specification of parameters associated the IEEE-488 and serial remote interfaces. Consult the *Remote Interface Reference* section beginning on page 61 for more information regarding the communication interfaces.

3.2.4.1 IEEE-488 Address

```
+50.00 A  -  IEEE-488 Address (0-30)
 +0.50 Vs      22
```

Specifies the IEEE-488 primary address of the Model 420. The valid range is from 0 to 30. The Model 420 should be assigned a unique primary address on the IEEE-488 bus. Enter a value or use the dial to adjust the value. The default primary address is 22. The Model 420 does not support secondary addressing.

3.2.4.2 Serial Baud Rate

```
+50.00 A  -  Serial Baud Rate
 +0.50 Vs     1200  2400  4800 ►9600
```

Specifies the baud rate of the serial interface. Use the **OPTION** key to cycle between values. The default value is 9600 baud.

3.2.4.3 Serial Data Bits/Parity

```
+50.00 A  -  Serial Data Bits/Parity
 +0.50 Vs     7/Even   7/Odd  ►8/None
```

Specifies the number of data bits and parity for the serial interface. Use the **OPTION** key to cycle between values. The default setting is no 8 data bits/no parity.

3.2.4.4 Serial Stop Bits

```
+50.00 A  -  Serial Stop Bits
 +0.50 Vs    ►1       2
```

Specifies the number of stop bits for the serial interface. Use the **OPTION** key to cycle between values. The default value is 1 stop bit.

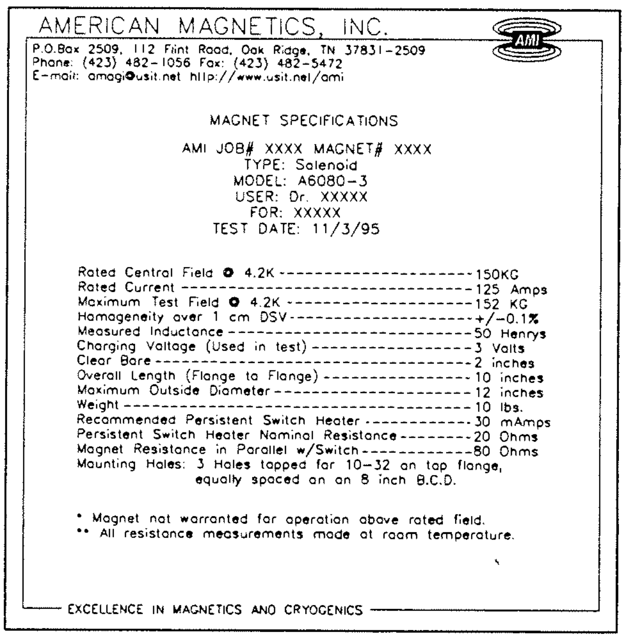
3.2.4.5 Serial Handshaking

```
+50.00 A   -   Serial Handshaking
 +0.50 Vs     ▸None      SW (XON/XOFF)
```

Specifies whether the serial interface uses no handshaking or software handshaking (commonly referred to as XON/XOFF). Hardware handshaking is not supported. Use the **OPTION** key to cycle between values. The default setting is no handshaking.

3.2.5 Example Setup

As a precursor to operating a superconducting magnet with the Model 420 programmer and power supply, all of the setup items should be reviewed and set if necessary with appropriate values for the connected superconducting magnet.



AMERICAN MAGNETICS, INC.
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E-mail: amagi@usit.net http://www.usit.net/ami

MAGNET SPECIFICATIONS

AMI JOB# XXXX MAGNET# XXXX
TYPE: Solenoid
MODEL: A6080-3
USER: Dr. XXXXX
FOR: XXXXX
TEST DATE: 11/3/95

Rated Central Field @ 4.2K ---------- 150KG
Rated Current ---------- 125 Amps
Maximum Test Field @ 4.2K ---------- 152 KG
Homogeneity over 1 cm DSV ---------- +/-0.1%
Measured Inductance ---------- 50 Henrys
Charging Voltage (Used in test) ---------- 3 Volts
Clear Bore ---------- 2 inches
Overall Length (Flange to Flange) ---------- 10 inches
Maximum Outside Diameter ---------- 12 inches
Weight ---------- 10 lbs.
Recommended Persistent Switch Heater ---------- 30 mAmps
Persistent Switch Heater Nominal Resistance ---------- 20 Ohms
Magnet Resistance in Parallel w/Switch ---------- 80 Ohms
Mounting Holes: 3 Holes tapped for 10-32 on top flange, equally spaced on an 8 inch B.C.D.

* Magnet not warranted for operation above rated field.
** All resistance measurements made at room temperature.

EXCELLENCE IN MAGNETICS AND CRYOGENICS

Figure 3-5. Example magnet specification sheet.

Figure 3-5 shows an example magnet specifications sheet. Several parameters needed to operate the magnet are specified. These values should be entered into the appropriate setup menu of the Model 420. For the purposes of this example, the AMI Model 12200PS power supply without an energy absorber will be assumed, since rated current for the example magnet is 125 A.

The current limits accessible in the limits setup submenu should be set to the rated current to prevent accidental operation of the magnet above rated current/field. The magnet specification sheet also indicates whether a persistent switch is installed and provides the recommended heating current. The persistent switch information is entered in the load setup submenu.

If your magnet, programmer, and power supply were purchased as a system from AMI, the setup menus are preset by AMI to match the magnet purchased.

Table 3-4 provides a summary of the Model 420 setup parameters for this example.

Table 3-4. Example Setup Configuration

Select Power Supply	AMI 12200PS
Stability Setting (%)	0.0
Coil Constant[a] (kG/A)	1.20000
Current Limit (A)	126.600[b]
PSwitch Installed?	YES
PSwitch Current (mA)	30.0
PSwitch Heated Time (sec)	15
Enable Quench Detect?	YES
Energy Absorber Present?	NO
Programmed Current (A)	125.0000
Voltage Limit (V)	5.000[c]
Ramp Rate (A/sec)	0.0600[d]

a. Also referred to as the Field-to-Current Ratio. Obtained by dividing the rated field by the rated current.
b. Value is the approximate current at the maximum test field.
c. Value is the 3 V charge rate plus allowances for power lead drop at the rated current.
d. Value is obtained by dividing the charge rate (V) by the inductance (H).

3.3 Ramping Functions

The ramping functions are used to control charging of the superconducting load. The Model 420 allows a piecewise-linear charging profile to be defined and executed. The basic charging equation for a superconducting magnet is:

$$V = L \frac{di}{dt}$$

where V is the charging voltage (V), L is the magnet inductance (Henries), and di/dt is the ramp rate (A/s). The relationship may also be defined in terms of a ramp rate in kG/s by the relationship:

$$V = \frac{L}{C} \frac{dF}{dt}$$

where C is the coil constant (or field-to-current ratio) in kG/A, and dF/dt is the ramp rate expressed in kG/s.

A desired ramp rate should be selected by the operator and entered into the Model 420. A voltage limit should also be specified that is greater than or equal to the voltage calculated from the equations above (remember to account for power lead resistance).

Once the ramp rate and voltage limit are specified, the Model 420 provides two modes of ramping operation: *manual* and *programmed*. The manual mode of operation will ramp to the current limit via manual direction control by the user. The programmed mode of operation ramps to a *programmed current or field* setting automatically. The programmed mode can be thought of as a "next point" operation, whereby the Model 420 determines the appropriate ramp direction based on the present magnet current and the programmed value.

3.3.1 Ramping States and Controls

The ramping state may be one of several values as described in Table 3-5.

If the **RAMP/PAUSE** key is illuminated, the PAUSED mode is active. To continue ramping in programmed mode, press the **RAMP/PAUSE** key to deactivate the PAUSED mode.

If manual mode operation is desired, press either the ▲ or ▼ keys for manual control ramping up or ramping down, respectively.

A voltage limit and ramp rate may be specified from quickly accessible menus from the front panel keypad. The settings for the voltage limit and the ramp rate are applicable to both the manual and programmed modes of operation.

Table 3-5. Ramping states and descriptions.

Mode	Description
Ramping	Automatic ramping to the programmed current or field[a] is in progress.
Holding	The programmed current has been achieved and is being maintained.
Paused	Ramping is suspended at the current achieved at the time the PAUSED mode was entered.
Manual	Ramping is being controlled by the **MANUAL CONTROL** functions available on the front panel.
Zeroing Current	The **ZERO** mode is active, and the instrument is ramping current to 0 A.
Heating Switch	The persistent switch heater has been activated. Ramping is disabled during the persistent switch heating period.

a. The programmed current/field setting is discussed in paragraph 3.3.3.1.

3.3.1.1 Voltage Limit

```
+50.00 A   -   Voltage Limit (V)
 +0.50 Vs      ±5.000
```

The voltage limit is accessed by pressing the **VOLTAGE LIMIT** key and may be set less than or equal to the maximum output voltage of the power supply (see Table 3-2 on page 39). The voltage limit does not require a sign since it functions as both the negative and positive limit. The voltage limit constrains the commanded output voltage of a connected power supply to a value less than or equal to the limit.

The voltage limit may be entered directly via the keypad or adjusted using the dial. Attempts to set the voltage limit above the maximum output of the power supply are ignored and, if attempted, the instrument will beep once indicating an error and revert to the previous setting.

3.3.1.2 Ramp Rate

```
+50.00 A  -  Ramp Rate (A/sec)
 +0.50 Vs      0.5000
```

The ramp rate is accessed by pressing the **RAMP RATE** key. The ramp rate may be set within the range specified in the specifications table for a specific Model 420 configuration (see page 7). Attempts to set the ramp rate outside of the valid range are ignored and, if attempted, the instrument will beep once indicating an error and revert to the previous setting. The ramp rate may be entered directly via the keypad or adjusted using the dial.

If the selected default display contains units of field, then the ramp rate setting is displayed and set in units of kilogauss/sec (or Tesla/sec) as show below. The allowable range is defined by the setting of the coil constant and the allowable range of the ramp rate in terms of current as specified on page 7.

```
+45.00 kG -  Ramp Rate (kG/sec)
 +0.50 Vs      0.4500
```

The Model 420 will ramp at the specified rate if the available compliance of the power supply is sufficient and the voltage limit is not exceeded. The Model 420 automatically decreases the ramp rate internally during operation if either the available compliance of the power supply is insufficient, or the voltage limit is active.

3.3.2 Ramping in Manual Mode

The two keys labeled as **MANUAL CONTROL** ▲ and ▼ control the ramping function in manual mode. If the ▲ is pressed and becomes illuminated, the Model 420 will *ramp up* at the ramp rate setting. The ramping may be paused by pressing the ▲ key again (or by pressing **RAMP/PAUSE**) to deactivate the manual up mode. Once deactivated, the **RAMP/PAUSE** key will become illuminated indicating that the PAUSED mode has been entered.

If the ▼ key is pressed, the Model 420 will *ramp down* at the ramp rate setting. The ramping may be paused by pressing the ▼ key again (or by pressing **RAMP/PAUSE**) to deactivate the manual down mode.

The manual up or down modes will continue ramping until paused or the *current limit for the magnet* specified in setup (see paragraph 3.2.2.3) is achieved.

3.3.3 Ramping in Programmed Mode

Ramping in programmed mode differs from the manual mode in that the Model 420 automatically performs ramping in the appropriate direction to achieve the value of the programmed current setting. Programmed mode is active when the ▲ or ▼ keys for the **MANUAL MODE** are *not* illuminated, and the **RAMP/PAUSE** key is *not* illuminated.

3.3.3.1 Programmed Current/Field

```
+50.00 A   -  Programmed Current (A)
 +0.50 Vs       +50.000
```

The programmed current is accessed by pressing the **PROGRAMMED CURRENT/FIELD** key and may be set less than or equal to the current limit for the magnet specified in setup (see paragraph 3.2.2.3). The programmed current requires a sign since it locates a single setpoint within the entire operating current range of the system.

If the selected default display mode contains field units, the display will allow entry of a *programmed field* value in units of kilogauss (or Tesla) as shown below. The programmed field must also be set within the current limit for the magnet.

```
+45.00 kG -  Programmed Field (kG)
 +0.50 Vs      +45.000
```

The programmed current/field setting may be entered directly via the keypad, or adjusted using the dial if the PAUSED mode is not active (see paragraph 3.3.5 if PAUSED is active). Attempts to set the programmed current/field above the current limit for the magnet are ignored and, if attempted, the instrument will beep once indicating an error and revert to the previous value.

3.3.4 Ramp to Zero Mode

If a quench condition does not exist, the **RESET/ZERO** key activates an immediate ramp to zero current. When the zero mode is activated, the **RESET/ZERO** key is illuminated and the Model 420 automatically ramps the current to 0 A at the set ramp rate while observing the voltage limit. The zero mode may be interrupted at any time by pressing the **RESET/ZERO** key to deactivate the function or pressing the ▲ , ▼ , or **RAMP/PAUSE** keys. If the **RESET/ZERO** key is deactivated, the Model 420 will automatically enter the PAUSED mode and maintain the operating current present at the point it was paused.

3.3.5 Dial Adjustment of Current/Field in PAUSED Mode

If the programmed current/field menu is active *and* the instrument is in PAUSED mode (indicated if the **RAMP/PAUSE** button is illuminated), the dial can be used to directly manipulate the operating (shunt) current.

Note

The encoder dial is velocity-sensitive, meaning that the faster the dial is turned, the more coarse the adjustment. Slow manipulation of the dial will yield very fine resolution even beyond that displayed by the instrument.

When the dial is manipulated the Model 420 will follow at a compliance of less than or equal to the voltage limit. The ramp rate setting is not observed in this operational mode, however, the voltage limit is strictly observed and is never exceeded.

Adjustment of the current in this mode is also prevented from exceeding the magnet current limit specified in the *Load* setup menu (see paragraph 3.2.2.3). The adjustment may, however, exceed the programmed current/field setting. The *resolution* of the adjustment is 15 digits, which is greater than the resolution of the display.

Caution

Entering a voltage limit via the **VOLTAGE LIMIT** *key or in the setup mode is strongly advised if you wish to adjust the current using this method. Otherwise, large changes using the dial can result in voltages across the terminals of the magnet capable of causing a quench in some magnets.*

3.3.6 Ramping Functions Example

As an example of ramping to two programmed current settings, refer to Figure 3-6 below. Each step is labeled as 1 through 8 in Figure 3-6. The Model 420, for the purposes of the example, is assumed to be in the PAUSED mode at 0 A at the beginning of the ramp.

Point 1. The operating current is 0 A and the Model 420 is in the PAUSED mode. The operator sets the programmed current to -30.000 A. The **RAMP/PAUSE** key is pressed so that the PAUSED mode is no longer active and the Model 420 begins ramping current.

Point 2. The programmed current setting of -30.000 A is achieved and the Model 420 switches to HOLDING mode.

Point 3. The operator increases the ramp rate setting. The operator also keys in a new value of +40.000 A for the programmed current setting. As

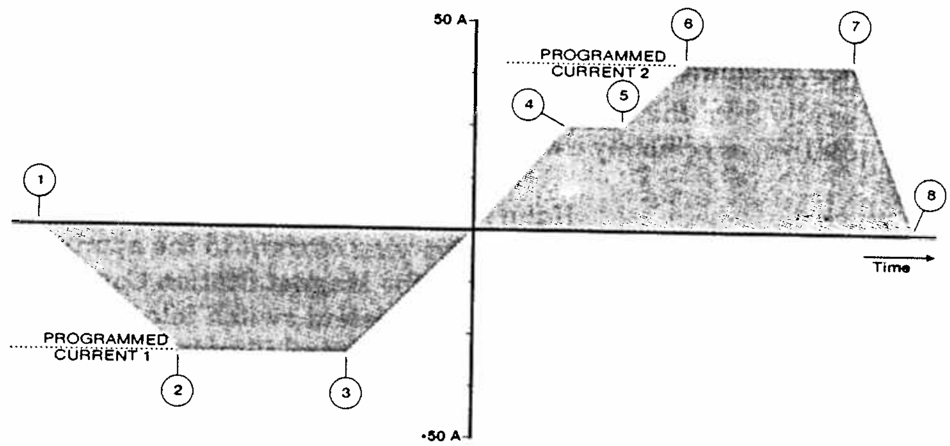


Figure 3-6. Example of ramping to two different programmed current settings.

soon as the new programmed current is entered, the Model 420 automatically begins ramping at the specified ramp rate.

Point 4. The operator presses the **RAMP/PAUSE** key at an operating current of 25.15 A and the PAUSED mode is activated. The Model 420 maintains the operating current in the PAUSED mode.

Point 5. The operator presses the **RAMP/PAUSE** key once again to resume ramping.

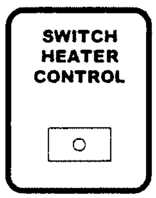
Point 6. The programmed current setting of +40.000 A is achieved and the Model 420 switches to HOLDING mode. At this point the operator deactivates the persistent switch heater which removes the magnet from the circuit.

Point 7. The operator increases the ramp rate and presses the **RESET/ZERO** key to begin ramping to zero current. The Model 420 automatically ramps the current to 0 A.

Point 8. The Model 420 holds the operating current of 0 A when achieved until the **RESET/ZERO** key is deactivated.

3.4 Persistent Switch Heater Control

The Model 420 includes an integral persistent switch heater that provides the capability of controlling the persistent mode of the magnet either locally from the front panel of the instrument using the switch heater control, or remotely through a communications interface.



If the switch heater control is illuminated, the Model 420 is supplying current to the appropriate pins (9 & 10) of the Magnet Station Connectors in order to drive the persistent switch into a normal state. The switch heater control illuminates if activated via the front panel, or if a remote command activates the heater.

The Model 420 will beep once (indicating an error) if the user attempts to activate the switch heater control without first indicating a persistent switch is installed in the load setup submenu and specifying the switch heating current and heating time (see page 44).

The nominal switch heating current is provided with the magnet specification sheet and may be entered in the Model 420 by accessing the load setup submenu (see paragraph 3.2.2.5). In addition to the *heating current*, the operator must also specify a *heating time*. The heating time allows the Model 420 to delay compensating the internal control logic until the magnet is guaranteed to be in the circuit. The heating time can be set from a minimum of 5 seconds to a maximum of 120 seconds within the load setup submenu (see paragraph 3.2.2.6). The default heating period of 15 seconds is adequate for the majority of persistent switches. If the magnet appears unstable just after the switch heating period expires, increase the switch heating time to allow for complete heating.

Note

During the period the switch is being heated, the Model 420 will not allow ramping functions to be executed and will beep once if the operator attempts to initiate a ramping operation.

3.4.1 Procedure for Entering Persistent Mode

In order to enter the persistent mode of magnet operation, the operator should perform the following steps:

1. Use either the programmed or manual ramping modes of the Model 420 to achieve the desired current or field.

2. The Model 420 should be in either the HOLDING or PAUSED mode at the desired current or field.

3. Record the desired current or field setting.

4. Deactivate the switch heater control (the LED indicator should extinguish).

5. Wait until the switch heater is completely cooled before changing any parameters. Most persistent switches cool to superconducting state in a few seconds if completely submerged in liquid helium.

6. Once the switch has cooled, the Model 420 may be used to ramp the current to zero at an increased ramp rate (since the magnet is no longer in the circuit). Using the ZERO mode is recommended since it allows the programmed current/field to remain unchanged for future sessions.

7. Once at zero current, de-energize the power supply first, then power-off the Model 420 instrument.

3.4.2 Procedure for Exiting Persistent Mode

To exit the persistent mode of magnet operation, the operator should perform the following steps:

1. If the Model 420 has been powered-off, then first energize the Model 420. After the Model 420 has been energized, energize the power supply.

2. Using the value of current or field recorded when the magnet last entered the persistent mode, use either the programmed or manual ramping modes of the Model 420 to achieve the last recorded value of current or field.

3. The Model 420 should be either in the HOLDING or PAUSED mode at the last recorded value of current or field.

4. Activate the switch heater control (the LED indicator should illuminate). Note that the Model 420 will enter the HEATING SWITCH mode and disallow any ramping during the switch heating period.

5. Once the switch heating period expires, the Model 420 will enter the PAUSED mode and will maintain the operating current or field.

   Note

   If the actual current in the magnet and the operating current of the Model 420 exhibit a mismatch at the time the switch heater is activated, the Model 420 will track the actual current of the magnet *during the switch heating period. At the expiration of the switch heating period, the Model 420 will attempt to maintain the last measured current value.*

3.4.3 Optional Switching of External Power Supply

The Model 420 offers the option of using an external power supply for the persistent switch heating current if the requirements for the switch heater exceed the capabilities of the integrated switch heating output of the Model 420. The external power supply, if properly connected, will be switched via an internal relay that opens and closes with the switch heater control functions of the Model 420.

To use an external power supply for the switch heater current, connect an external power supply to J4 pins 4 and 5 (any polarity). Then connect pins 18 and 19 of J7A or J7B to the switch heater terminals of the superconducting magnet. Ensure that the external power requirements are within the limits shown in the specifications table on page 7.

3.5 Quench Detection

The Model 420 continuously monitors the superconducting magnet load and can automatically detect a quench condition. If a quench is detected, the quench detection LED will become illuminated and the display will appear as shown below. When a quench is detected, the Model 420 automatically sets the power supply output voltage to zero, provides a quench output signal to the rear panel connector J4 (see page 104 of the *Appendix* for the connector pinout), and will not respond to further input until the **RESET/ZERO** button is pressed to clear the quench detect condition, or until the quench condition is cleared by a remote command.

```
+44.36 A     Quench Detected @ +80.56 A
 +0.00 Vs    PSwitch Heater: ON
```

If the **RESET/ZERO** key is pressed to clear the quench condition or a remote clear command is issued, the Model 420 will automatically enter the PAUSED mode and will attempt to maintain the operating current present at the point the quench condition was cleared.

In addition, the rear panel connector, J4, provides pins for external quench input (see page 104 of the *Appendix* for the connector pinout). If the quench input is asserted, then the Model 420 interprets this input as indication of a quench condition and the Model 420 automatically sets the power supply output voltage to zero and will not respond to further input until the **RESET/ZERO** button is pressed to clear the quench detect condition, or until the quench condition is cleared by a remote command. The rear panel input cannot be disabled, however, it may be left unconnected without the possibility of a generating a false quench condition.

Note

If the external quench detection circuit continues to assert the quench detection input of the Model 420, the **RESET/ZERO** *key will be unable to clear the quench condition.*

3.5.1 Disabling Automatic Quench Detection

The automatic quench detection feature may be disabled in the load setup submenu (see paragraph 3.2.2.7). However, the rear panel quench detect input (connector J4) remains active.

If the automatic quench detection feature is disabled, the Model 420 attempts to limit the error, between the commanded current and the present operating current, to a value that will not result in excessive voltages being introduced across the magnet terminals. Under most operating conditions this will not damage any internal protection circuits of the magnet. If an actual quench condition occurs, the Model 420 will follow the magnet current to zero unless the operator intervenes. If the rear panel quench detect input (connector J4) is asserted, the Model 420 will force the power supply output to zero volts regardless of whether the automatic quench detection is enabled or disabled.

In the event that the persistent switch becomes normal without operator or remote activation of the switch heater control, the Model 420 will match the magnet current and attempt to stabilize the load *if the automatic quench detection feature is disabled.* If the automatic quench detection feature is *enabled,* then this event will generally trigger the quench detection logic if a difference exists between the magnet current and the operating current of the Model 420.

3.6 Summary of Operational Limits and Default Settings

Table 3-6 provides a summary of the operational limits and the default setting for all Model 420 parameters. If the operator attempts to enter a value outside of the limits, the Model 420 will beep once and revert to the previous setting.

References to the specifications on page 7 indicate that the absolute limit is determined by the specific configuration of the Model 420 purchased.

Table 3-6. Summary of limits and defaults for the Model 420.

Model 420 Setting (Units)	Absolute Limits	Default Setting[a]
Min Output Voltage (V)	0.000 to –20.000	0.000
Max Output Voltage (V)	0.001 to +20.000	12.000
Min Output Current (A)	(see page 7)	0.000
Max Output Current (A)	(see page 7)	100.000
V-V Mode Input Range (V)	–10.000 to +10.000	0.000 to +10.000
Stability Setting (%)	0.0 to 100.0	0.0
Coil Constant (kG/A)	0.001 to 999.99999	0.0
PSwitch Current (mA)	0.1 to 100.0	10.0
PSwitch Heated Time (sec)	5 to 120	15
Current Limit (A)	≥ Min Output Current *and* ≤ Max Output Current	80.000
Display Contrast (%)	0 to 100	80
Voltage Limit (V)	≥ 0.001 *and* ≤ Max Output Voltage	2.000
Ramp Rate (A/sec)	(see page 7)	0.100
Programmed Current (A)	≤ Current Limit	5.000

a. Unless preset by factory.

4 Remote Interface Reference

The Model 420 provides both RS-232 and IEEE-488 interfaces as standard features. Upon request, the RS-232 port can be reconfigured for RS-422 operation. The serial and IEEE-488 interfaces may operated simultaneously. Separate output buffers are also provided for the serial and IEEE-488 return data. However, for optimal performance and simplicity of programming, AMI normally recommends limiting operation to one interface. An exception to this recommendation would be using the serial port as a debugging aid during programming of the IEEE-488 port (or vice-versa), which can prove to be a useful resource.

4.1 SCPI Command Summary

The following manual conventions are used for SCPI (*Standard Commands for Programmable Instruments*) syntax for the remote interface commands:

- Braces { } enclose valid parameter choices.
- A vertical bar | separates multiple choices for each parameter.
- Triangle brackets < > indicate that you must supply a value.
- Parentheses ( ) within < > indicate alternative units are available.

For example, the command `PSwitch {0|1}` indicates that the command `PSwitch` has two parameter options: `0` or `1`. Refer to the detailed description of each command for information regarding specific parameter choices and their meanings. Capitalized portions of the commands indicate acceptable abbreviations. Default settings are shown in bold.

System-Related Commands

(see page 75 for more information)

`*IDN?`
`*RST`
`*TST?`
<Ctrl-C>

`SYSTem:LOCal`
`SYSTem:REMote`
`SYSTem:TIME?`
`SYSTem:TIME:RESet`
`SYSTem:ERRor?`

Status System Commands

(see page 76 for more information)

```
*STB?
*SRE <enable_value>
*SRE?

*CLS

*ESR?
*ESE <enable_value>
*ESE?

*PSC {0|1}
*PSC?
*OPC
*OPC?
```

SETUP Configuration Commands

(see page 78 for more information)

```
CONFigure:VOLTage:MINimum <voltage>
CONFigure:VOLTage:MAXimum <voltage>

CONFigure:CURRent:MINimum <current>
CONFigure:CURRent:MAXimum <current>

CONFigure:STABility <percent>
CONFigure:COILconst <value>
CONFigure:CURRent:LIMit <current>

CONFigure:PSwitch {0|1}
CONFigure:PSwitch:CURRent <current>
CONFigure:PSwitch:TIME <time>

CONFigure:QUench:DETect {0|1}
CONFigure:ABsorber {0|1}

CONFigure:RAMP:RATE:UNITS {0|1}
CONFigure:FIELD:UNITS {0|1}
```

SETUP Configuration Queries

(see page 78 for more information)

```
VOLTage:MINimum?
VOLTage:MAXimum?

CURRent:MINimum?
CURRent:MAXimum?

STABility?
COILconst?
CURRent:LIMit?

PSwitch:CURRent?
PSwitch:TIME?

QUench:DETect?
ABsorber?

RAMP:RATE:UNITS?
FIELD:UNITS?
```

Ramp Configuration Commands and Queries

(see page page 81 for more information)

CONFigure:VOLTage:LIMit *<voltage>*

CONFigure:CURRent:PROGram *<current>*
CONFigure:FIELD:PROGram *<field (kG, T)>*

CONFigure:RAMP:RATE:CURRent *<rate (A/s, A/min)>*
CONFigure:RAMP:RATE:FIELD *<rate (kG/s, kG/min, T/s, T/min)>*

CONFigure:RAMP:CURRent *<current>,<rate (A/s, A/min)>*
CONFigure:RAMP:FIELD *<field (kG, T)>,<rate (kG/s, kG/min, T/s, T/min)>*

VOLTage:LIMit?

CURRent:PROGram?
FIELD:PROGram?

RAMP:RATE:CURRent?
RAMP:RATE:FIELD?

RAMP:CURRent?
RAMP:FIELD?

VOLTage:MAGnet?
VOLTage:SUPPly?
CURRent:MAGnet?
FIELD:MAGnet?

Ramping State Commands and Queries

(see page 83 for more information)

RAMP
PAUSE
UP
DOWN
ZERO

STATE?

Switch Heater Commands and Queries

(see page 84 for more information)

```
PSwitch {0|1}
PSwitch?
```

Quench State Control and Queries

(see page 84 for more information)

```
QUench {0|1}
QUench?
```

Trigger Control and Queries

(see page 85 for more information)

```
*ETE <enable_value>
*ETE?
*TRG
```

4.2 Programming Overview

The Model 420 conforms to the SCPI (*Standard Commands for Programmable Instruments*) IEEE standard. The SCPI standard is an ASCII-based specification designed to provide a consistent command structure for instruments from various manufacturers.

The Model 420 also implements a status system for monitoring the state of the Model 420 through the *Standard Event* and *Status Byte* registers.

4.2.1 SCPI Language Introduction

SCPI commands conform to a tree structure where commands are grouped according to common keywords. For example, commands which set a Model 420 setup or operating parameter begin with the keyword `CONFigure`. The keywords are shown in upper case and lower case to indicate acceptable abbreviations. For the example keyword `CONFigure`, the user may send either the abbreviated form of `CONF`, or the entire keyword `CONFIGURE`. Any other form of the keyword is illegal and will generate an error.

Many commands also require multiple keywords to traverse the tree structure of the entire Model 420 command set. For example, commands associated with a current setting require the prefix of `CONFigure:CURRent`. Note that a colon (:) separates the keywords. No spaces are allowed before or after the colon. Parameters must be separated from the command keyword(s) by at least one space.

4.2.2 SCPI Status System

The Model 420 status system reports various conditions of the instrument in two registers groups shown in Figure 4-1. The register groups consist of a condition or event register, and an enable register which controls the actions of specific bits within the condition or event registers.

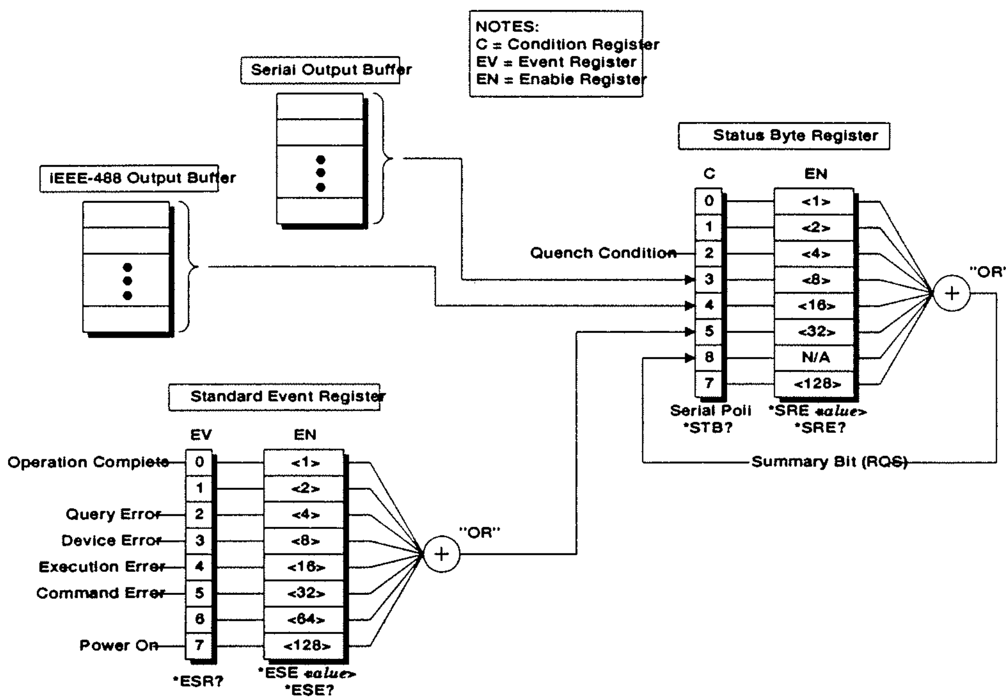


Figure 4-1. The Model 420 status system.

A *condition* register continuously monitors the state of the instrument. The bits of a condition register are updated in real time. A condition register is read-only and is not cleared when you read the register. A query of a condition register returns a decimal value in the appropriate output buffer which corresponds to the binary-weighted sum of all bits set in the register.

An *event* register latches various events. An event register is not buffered, therefore once a bit is set, further occurrences of that event are ignored. Once a bit is set in an event register, the bit remains set until the register is read (`*ESR?`) or a `*CLS` (clear status) command is issued. A query of an event register returns a decimal value in the appropriate output buffer which corresponds to the binary-weighted sum of all bits set in the register.

An *enable* register (or bitmask) defines which bits in an event register are reported to the Status Byte register group. An enable register can be both written and queried. The `*CLS` (clear status) command does not clear an enable register. To enable or disable bits in an enable register, write a decimal value which corresponds to the binary-weighted sum of the bits you wish reported to the Status Byte register.

4.2.2.1 Status Byte Register

The Status Byte register group reports conditions from the Standard Event register or output buffers. Data in the output buffer is immediately reported in the "IEEE-488 Message Available" bit (bit 4) or the "Serial Message Available" bit (bit 3). Clearing a bit in the Standard Event register will update the corresponding bit in the Status Byte register, according to the Standard Event enable register. Reading the pending messages in the output buffers will clear the appropriate "Message Available" bit. The bit definitions for the Status Byte register are defined in Table 4-1.

Table 4-1. Bit definitions for the Status Byte register.

Bit Number	Decimal Value	Definition
0 *Not Used*	1	Always "0".
1 *Not Used*	2	Always "0".
2 Quench Condition	**4**	The Model 420 has detected a quench.
3 Serial Message Available	**8**	The serial output buffer contains unread data.
4 IEEE-488 Message Available	**16**	The IEEE-488 output buffer contains unread data.
5 Standard Event	**32**	One or more enabled bits are set in the Standard Event register.
6 Status Byte Summary	**64**	One or more enabled bits are set in the Status Byte register.
7 *Not Used*	128	Always "0".

The Status Byte register provides the capability of generating a user-defined IEEE-488 service request (SRQ) by enabling the desired bits using the `*SRE` *<value>* command. If a Status Byte register bit is enabled, then when that bit is set, an SRQ is generated on the IEEE-488 bus. For example, if the command `*SRE 4` is sent to the Model 420, then if a quench detect subsequently occurs, the Model 420 will immediately generate an SRQ on the IEEE-488 bus.

Bit 2 of the Status Byte register, indicating a quench condition, remains set until the quench condition is cleared via the front panel or by remote command. However, an SRQ is only asserted when the quench is *first detected*. Bits 3 and 4, indicating available data in an output buffer, are similar in that the SRQ is only asserted when data is first available in an output buffer. Bits 3 and 4 remain set until all data has been read from the respective output buffer.

The Status Byte *condition register* is cleared when:

- A `*CLS` command is executed.
- The Standard Event register is read (only bit 5 of the Status Byte register is cleared).
- The indicated condition no longer exists.

The Status Byte *enable register* is cleared when:

- The `*SRE 0` command is executed.
- The power is turned off and then back on, and the instrument was configured for `*PSC 1` (power-on status clear). The enable register setting is persistent if the Model 420 is configured for `*PSC 0` (no status clear on power-on).

4.2.2.2 Serial Polling and the Service Request (SRQ)

In order to use the SRQ feature of the Model 420, you must configure your host computer and IEEE-488 interface card to respond to the IEEE-488 service request. If the Status Byte enable register enables any bits of the Status Byte register, then the enabled bit(s) will generate an SRQ when they transition from "0" to "1". The host computer can then poll the instruments on the IEEE-488 bus to determine which is asserting the service request line (the instrument which returns a response to a Serial Poll with bit 6 set).

Note

If the Model 420 receives a Serial Poll, bit 6 of the Status Byte register is cleared and the service request line (SRQ) is cleared.

If more than one bit is enabled in the Status Byte enable register, then the user must query the Status Byte register by issuing either a Serial Poll message, or the `*STB?` command. A Serial Poll is executed immediately by the Model 420 and may not reflect the effects of the most recently executed command. Use the *OPC? command for positive indication that all prior commands have been executed.

4.2.2.3 Reading the Status Byte using *STB?

The *STB? returns the contents of the Status Byte register, but it is processed in the command queue like any other command. The *STB? command returns the same result as a Serial Poll, however bit 6 of the Status Byte register is not cleared. Issuing an *STB? query does not clear an SRQ condition.

4.2.2.4 Using the Message Available Bit(s)

The "Message Available" bits (bits 3 or 4) of the Status Byte register can be used to determine when data is available to read into your host computer. The instrument clears the "Message Available" bits only after all data has been read from the output buffer(s).

The "Message Available" bits of the Status Byte register are useful for determining if *queries* have executed, however, they are not useful alone for determining if *commands* have completed execution, since commands do not provide return data.

4.2.3 Standard Event Register

The Standard Event register group reports a power-on condition, various error conditions, and indicates when an operation has completed. Any or all of the Standard Events can be reported to the Status Byte register by enabling the corresponding bit(s) in the Standard Event enable register (see Figure 4-1). To set the Standard Event enable register, write a binary-weighted decimal value using the *ESE *<value>* command.

The bit definitions for the Standard Event register are provided in Table 4-2. To query the instrument for the details of a reported error in the Standard Event register, use the SYSTem:ERRor? query. See paragraph 4.6 for a complete discussion of the error buffer and messages.

The Standard Event *register* is cleared when:

- The *CLS (clear status) command is executed.
- The Standard Event register is queried using the *ESR? command.

The Standard Event *enable register* is cleared when:

- The *ESE 0 command is executed.
- The power is turned off and then back on, and the instrument was configured for *PSC 1 (power-on status clear). The enable register setting is persistent if the Model 420 is configured for *PSC 0 (no status clear on power-on).

Table 4-2. Bit definitions for the Standard Event register.

Bit Number	Decimal Value	Definition
0 Operation Complete	**1**	All commands prior to and including `*OPC` have been executed.
1 *Not Used*	2	Always “0”.
2 Query Error	**4**	A query error occurred. See the error messages in the -200 range.
3 Device Error	**8**	A device error occurred. See the error messages in the -400 range.
4 Execution Error	**16**	An execution error occurred. See the error messages in the -300 range.
5 Command Error	**32**	A command error occurred. See the error messages in the -100 range.
6 *Not Used*	64	Always “0”.
7 Power On	**128**	Power has been cycled since the last time the Standard Event register was read or cleared.

4.2.4 Command Handshaking

The Model 420 provides an internal command queue that can store up to 4 commands or queries. However, it is possible that the host computer can overwhelm the command queue by sending commands faster than the Model 420 can execute. If the Model 420 cannot process a command due to a full command queue, the command is ignored and the `-303,"Input overflow"` error is reported.

Handshaking is generally not a concern unless more than 4 *commands* are sent sequentially. If a *query* is sent, the user will normally wait for return data for the queries before proceeding to send the next query or command. In the case of sending numerous *commands* in sequence, there are two methods available to help prevent command queue overflows which are discussed below.

4.2.4.1 Using the `*OPC` Command

The `*OPC` command is executed within the normal command queue. Upon completed execution of the `*OPC` command, the “Operation Complete” bit (bit 0) of the Standard Event register will be set.

If the operator has so configured the Standard Event and Status Byte enable registers, the *OPC command can generate an IEEE-488 service request when execution completes (see Figure 4-1). If using the serial port, the *OPC? query is a better alternative since a response is returned directly to the requesting communications interface.

An example of a sequence of commands using the *OPC command to handshake is the following:

```
CONF:RAMP:CURR 50.0, 0.1; CONF:VOLT:LIM 5.0; *OPC;
```

The above example sets the programmed current to 50.0 A, the ramp rate to 0.1 A/s, the voltage limit to 5.0 V, and sends as the third command the *OPC command for determining when execution all of the commands (including *OPC) is completed. If the Standard Event and Status Byte enable registers are correctly configured, the *OPC command will then result in an IEEE-488 service request when execution completes. Alternately, the Serial Poll function of the IEEE-488 bus may be used to determine completion of the command.

4.2.4.2 Using the *OPC? Query

The *OPC? query is similar to the *OPC command, but instead of setting the "Operation Complete" bit of the Standard Event register, the *OPC? query returns a "1" (plus termination characters) to the appropriate output buffer when executed. Using *OPC? is often the simpler solution for determining completed command execution. It is also unambiguous during simultaneous serial and IEEE-488 operation since the result is returned directly to the requesting communication interface.

4.3 RS-232/422 Configuration

The Model 420 allows several parameters related to the RS-232/422 interface to be configured by the user. See the *Comm Setup Submenu* description in paragraph 3.2.4 on page 47 for illustrations of the menus provided for configuring the Model 420 serial interface.

The *Comm Setup Submenu* provides menus to configure the following (the defaults are shown in bold):

- *Baud Rate*: 1200, 2400, 4800, **9600**
- *Parity and Data Bits*: Even Parity/7 Data Bits, Odd Parity/7 Data Bits, **No Parity/8 Data Bits**
- *Number of Start Bits*: **1 bit** (fixed)
- *Number of Stop Bits*: **1 bit** or 2 bits
- *Flow Control*: **None** or SW (XON/XOFF)

4.3.1 Serial Port Connector

An IBM-compatible computer's serial port can be directly connected to the Model 420 via a standard PC modem cable if the Model 420 is configured for RS-232. Refer to your computer's documentation to determine which serial ports are available on your computer and the required connector type. The cable to connect two DB25 connectors is wired directly, i.e. pin 1 to pin 1, pin 2 to pin 2, etc. If a DB9 connector is required at the computer interface, the connector translation is provided in the *Appendix*.

The Model 420, when configured for RS-232, uses only three wires of the rear-panel DB25 connector: pin 2 (receive), pin 3 (transmit), and pin 7 (common). The RS-232 (and RS-422) pinout is fully documented on page 107 in the *Appendix*. The Model 420 is classified as a DCE (Data Communication Equipment) device since it transmits data on pin 3 and receives data on pin 2. The computer or terminal to which the Model 420 is attached must do the opposite, i.e., transmit on pin 2 and receive on pin 3 (the requirements for a DTE, or Data Terminal Equipment device). If a serial-to-parallel converter is used, it must be capable of receiving data on pin 3 or the cable connected to the Model 420 must interchange the wires between pins 2 and 3.

Optional RS-422 connector pinout is provided in Table A-7 on page 108.

4.3.2 Termination Characters

All commands and queries are transmitted and received as ASCII values and are case insensitive. The Model 420 always transmits *<CR><LF>* (i.e. a *carriage return* followed by a *linefeed*) at the end of an RS-232 transmission. The Model 420 can accept *<CR>*, *<LF>*, *<CR><LF>*, or

<LF><CR>, or a semicolon (;) as termination characters from an external computer.

4.3.3 Flow Control Modes

The operator may select between two flow control modes for data transfers between the host device and the Model 420:

- *None*: Data is sent and received over the interface with no flow control. When using this mode, avoid sending more than 64 characters without stopping or reading a response.
- *Software*: Also referred to as *XON/XOFF*. Software handshaking uses special embedded characters in the data stream to control the flow. If the Model 420 is asked to return data, it continues data output until the XOFF character (13 Hex) is received. Once an XOFF character is received, an XON character (11 Hex) is required for data transmission to continue.

  The Model 420 also sends XON/XOFF when its internal serial port buffer reaches a "high-water" mark. The host device should suspend transmission on receipt of an XOFF character from the Model 420, and resume when an XON character is received.

  Note

  The XON/XOFF flow control should not be used as a substitute for command handshaking as documented in paragraph 4.2.4. XON/XOFF characters are not generated in the case of "input overflow" errors (error number -303).

4.4 IEEE-488 Configuration

The Model 420 allows the primary IEEE-488 address of the Model 420 to be configured by the user. See the *Comm Setup Submenu* description in paragraph 3.2.4 on page 47 for an illustration of the menu provided for configuring the Model 420 IEEE-488 address.

4.4.1 Termination Characters

All commands are transmitted and received as ASCII values and are case insensitive. The Model 420 always transmits *<LF>* with EOI as the termination for return data. The Model 420 can accept *<CR>*, *<LF>*, or *<LF>* with EOI as termination characters from an external IEEE-488 interface. More than one command may be sent before a terminator if each command is separated with a semicolon (;).

4.4.2 Device Clear

The Device Clear is a low-level IEEE-488 bus message which you can use to return the instrument to a responsive state if communication appears to stall. The status registers and the error queue are left unchanged when a Device Clear message is received. Device Clear performs the following actions:

- The Model 420's serial and IEEE-488 output buffers are cleared.
- The Model 420 is prepared to accept a new command.

Note

For the serial interface, a Device Clear can be initiated by sending the <Ctrl-C> (ASCII code 03) character.

4.4.3 Trigger Command

The trigger command is a low-level IEEE-488 bus message which you can use to initiate the trigger functions provided by the Model 420. The trigger functions supported by the Model 420 are documented in paragraph 4.5.8 on page 85. When a trigger command is received by the Model 420, the appropriate data is loaded into the output buffer(s) as selected by the `*ETE` *<value>* setting. The data provided is sampled within 25 milliseconds of the receipt of the trigger command.

Note

The serial interface can also initiate a trigger function by using the `*TRG` *command.*

4.5 Command Reference

The following paragraphs present all instrument commands and queries in related groups and a detailed description of the function of each command or query is provided. Examples are also provided where appropriate. Return strings may be up to 80 characters in length.

4.5.1 System-Related Commands

- `*IDN?`

Return the instrument's identification string. The identification string contains the AMI model number and firmware revision code.

- `*RST`

Resets the instrument. This is equivalent to cycling the power to the instrument using the power switch. All non-volatile calibration data and battery-backed memory is restored. Status is cleared according to the `*PSC` setting.

- `*TST?`

Performs a self-test. Currently always returns "1".

- *<Ctrl-C>*

Equivalent to sending a Device Clear message over the IEEE-488 interface. *<Ctrl-C>* is only accepted from the serial interface. This clears the output buffers of the instrument and prepares the instrument for a new command. Status registers are unaffected. *<Ctrl-C>* corresponds to ASCII code 03.

- `SYSTem:LOCal`

Enables all front panel controls. All front panels controls are enabled by default after a power-up or `*RST` command.

- `SYSTem:REMote`

> **Note**
>
> *The SYSTem:REMote command only disables the front panel controls for purposes of preventing accidental operation of a front panel feature. It is **not** necessary for this command to be sent prior to using a remote interface. Send the SYSTem:LOCal command, cycle instrument power, or send the *RST command to reenable the front panel controls.*

Disables all front panel controls. If the Model 420 is in the remote mode, an asterisk (*) will appear in the front panel display in the position just below the ramping character as shown below.

```
+50.00 kG ↑  Status: Ramping
 +1.50 Vs *  PSwitch Heater: ON
```

Figure 4-2. Illustration of asterisk annunciator indicating the Model 420 is in remote mode (all front panel controls are disabled).

• `SYSTem:TIME?`

Returns the instrument's time, in the format *hh:mm:ss.ss*, since the last power-on event or `SYSTem:TIME:RESet` command. The time wraps to 00:00:00.00 every 24 hours. The time is accurate to 25 milliseconds.

• `SYSTem:TIME:RESet`

Resets the instrument's time to 00:00:00.00.

• `SYSTem:ERRor?`

Queries the instrument's error buffer. Up to 10 errors are stored in the instrument's error buffer. Errors are retrieved in first-in-first-out (FIFO) order. The error buffer is cleared by the `*CLS` (clear status) command or when the power is cycled. Errors are also cleared as they are read. See page 87 for a complete description of the error buffer and messages.

4.5.2 Status System Commands

The status system register groups and commands are illustrated in Figure 4-1 on page 66.

• `*STB?`

Returns the contents of the Status Byte register. The `*STB?` command is similar in function to an IEEE-488 Serial Poll, however the command is executed in the order received as any other command. In contrast to the IEEE-488 Serial Poll, `*STB?` does not clear an SRQ condition or the "Summary Bit" (bit 6) of the Status Byte register.

• `*SRE` *<enable_value>*

Enables bits in the Status Byte register to be reported in the "Summary Bit" (bit 6) of the Status Byte register. To enable bits, you must write a decimal *<enable_value>* which corresponds to the binary-weighted sum of the bits you wish to enable. Refer to Table 4-1 on page 67 for more information. For example, to enable quench detections only in the "Summary Bit" of the Status Byte register, send the command:

```
*SRE 4;
```

• *SRE?

The *SRE? query returns a decimal sum which corresponds to the binary-weighted sum of the bits enabled by the last *SRE command.

• *CLS

Clears the Standard Event register and the error buffer.

• *ESR?

Returns the contents of the Standard Event register as a binary-weighted sum.

• *ESE *<enable_value>*

Enables bits in the Standard Event register to be reported in the "Standard Event" bit (bit 5) of the Status Byte register. To enable bits, you must write a decimal *<enable_value>* which corresponds to the binary-weighted sum of the bits you wish to enable. Refer to Table 4-2 on page 70 for more information. For example, to enable *all* categories of error messages to be reported in bit 5 of the Status Byte register, send:

```
*ESE 60;
```

• *ESE?

The *ESE? query returns a decimal sum which corresponds to the binary-weighted sum of the bits enabled by the last *ESE command.

• *PSC {0|1}

Power-On Status Clear. If *PSC 1 is in effect, the Standard Event enable register and the Status Byte enable register are cleared at power on. If *PSC 0 is in effect, the enable registers are not cleared at power on. The default setting is "1".

• *PSC?

Returns the *Power-On Status Clear* setting currently in effect. A value of "0" indicates the enable registers are not cleared at power on; a value of "1" indicates the enable registers are cleared at power on.

• *OPC

Sets the "Operation Complete" bit (bit 0) of the Standard Event register when executed. See page 70 for a complete discussion.

• *OPC?

Returns "1" to the requesting interface when executed. See page 71 for more information.

4.5.3 SETUP Configuration Commands and Queries

The SETUP Configuration Commands and Queries provide read/write access to the setup functions available within the *Supply* (see page 38), *Load* (see page 42), and *Misc* (see page 46) setup submenus.

> **Note**
>
> *The following eight commands set or return parameters associated with the power supply. These parameters specify the capabilities of the connected power supply and are not to be used for setting operational limits for the magnet. Use the CONF:CURR:LIM and CONF: VOLT:LIM commands to control the operational limits.*
>
> *If the following power supply parameters are changed during operation, the I / O scaling of the Model 420 may be in error and can result in possibly damaging voltage and / or current transients during magnet operation. Use the following eight commands with extreme care.*

- `CONFigure:VOLTage:MINimum` *<voltage>*

Sets the minimum *power supply* compliance in volts. For unipolar supplies, the minimum voltage is zero volts.

- `VOLTage:MINimum?`

Returns the minimum *power supply* compliance setting in volts.

- `CONFigure:VOLTage:MAXimum` *<voltage>*

Sets the maximum *power supply* compliance in volts.

- `VOLTage:MAXimum?`

Returns the maximum *power supply* compliance in volts.

- `CONFigure:CURRent:MINimum` *<current>*

Sets the minimum output current capacity of the *power supply* in amperes. For unipolar power supplies, the minimum output current is 0 A.

- `CURRent:MINimum?`

Returns the minimum output current capacity of the *power supply* in amperes.

- `CONFigure:CURRent:MAXimum` *<current>*

Sets the maximum output current capacity of the *power supply* in amperes.

- `CURRent:MAXimum?`

Returns the maximum output current capacity of the *power supply* in amperes.

• `CONFigure:STABility` *<percent>*

Sets the stability setting in percent.

• `STABility?`

Returns the stability setting in percent.

• `CONFigure:COILconst` *<value>*

Sets the coil constant (also referred to as the field-to-current ratio). The coil constant must be set to a non-zero, positive value in order to command or query the Model 420 in units of field.

• `COILconst?`

Returns the coil constant setting.

• `CONFigure:CURRent:LIMit` *<current>*

Sets the *magnet* current limit in amperes. The current limit is the largest magnitude operating current allowed during any ramping mode. For four-quadrant power supplies, the current limit functions as both a positive and negative current limit.

• `CURRent:LIMit?`

Returns the *magnet* current limit in amperes.

• `CONFigure:PSwitch {0|1}`

Sending "0" indicates that a persistent switch is not installed on the connected superconducting magnet. "1" indicates that a persistent switch is installed. If a persistent switch is installed, the persistent switch heating current and time should be specified. The default value is "1".

• `CONFigure:PSwitch:CURRent` *<current>*

Sets the persistent switch heater current in milliamperes.

• `PSwitch:CURRent?`

Returns the persistent switch current setting in milliamperes.

• `CONFigure:PSwitch:TIME` *<time>*

Sets the time required in seconds for the persistent switch heater to become resistive after the persistent switch heater has been activated.

• `PSwitch:TIME?`

Returns the persistent switch heating time in seconds.

- `CONFigure:QUench:DETect {0|1}`

Sending “0” disables the automatic quench detection function of the Model 420. “1” enables the automatic quench detection function of the Model 420. See page 58 for more information. “1” is the default value.

- `QUench:DETect?`

Returns “0” indicating automatic quench detection is disabled, or “1” indicating that the automatic quench detection is enabled.

- `CONFigure:ABsorber {0|1}`

Sending “0” indicates that an energy absorber is not present in the system. A “1” indicates that an energy absorber is present. “0” is the default value.

- `ABsorber?`

Returns “0” indicating that an energy absorber is not present in the system, or “1” indicating that an energy absorber is present.

- `CONFigure:RAMP:RATE:UNITS {0|1}`

Sets the preferred ramp rate time units. Sending “0” selects seconds. A “1” selects minutes. “0” is the default value. The selected units are applied to both the Model 420 display and the appropriate remote commands.

- `RAMP:RATE:UNITS?`

Returns “0” for ramp rates displayed/specified in terms of seconds, or “1” for minutes.

- `CONFigure:FIELD:UNITS {0|1}`

Sets the preferred field units. Sending “0” selects kilogauss. A “1” selects Tesla. “0” is the default value. The selected field units are applied to both the Model 420 display and the appropriate remote commands.

- `FIELD:UNITS?`

Returns “0” for field values displayed/specified in terms of kilogauss, or “1” for Tesla.

4.5.4 Ramp Configuration Commands and Queries

The ramp configuration commands set the various parameters required for defining piecewise-linear ramp segments. Also included are queries for collecting the magnet current, field, and voltage. See paragraph 3.3 on page 50 for more information regarding the ramping functions of the Model 420.

- `CONFigure:VOLTage:LIMit` *<voltage>*

Sets the ramping voltage limit in volts. The ramping voltage limit may not exceed the maximum output voltage of the power supply.

- `VOLTage:LIMit?`

Returns the ramping voltage limit in volts.

- `CONFigure:CURRent:PROGram` *<current>*

Sets the programmed current in amperes.

- `CURRent:PROGram?`

Returns the programmed current setting in amperes.

- `CONFigure:FIELD:PROGram` *<field (kG, T)>*

Sets the programmed field in units of kilogauss or Tesla, per the selected field units. This command requires that a coil constant be defined, otherwise an error is generated.

- `FIELD:PROGram?`

Returns the programmed field setting in units of kilogauss or Tesla, per the selected field units. This query requires that a coil constant be defined, otherwise an error is generated.

- `CONFigure:RAMP:RATE:CURRent` *<rate (A/s, A/min)>*

Sets the ramp rate in units of amperes/second or amperes/minute, per the selected ramp rate units.

- `RAMP:RATE:CURRent?`

Returns the ramp rate setting in units of amperes/second or amperes/minute, per the selected ramp rate units.

- `CONFigure:RAMP:RATE:FIELD` *<rate (kG/s, kG/min, T/s, T/min)>*

Sets the ramp rate in units of kilogauss/second or minute, or Tesla/second or minute (per the selected field units and ramp units). This command requires that a coil constant be defined, otherwise an error is generated.

• `RAMP:RATE:FIELD?`

Returns the ramp rate setting in units of kilogauss/second or minute, or Tesla/second or minute (per the selected field units and ramp units). This query requires that a coil constant be defined, otherwise an error is generated.

• `CONFigure:RAMP:CURRent` *<current>, <rate (A/s, A/min)>*

Sets both the programmed current in amperes, and the ramp rate in amperes/second or amperes/minute (per the selected ramp units), with one command string. Note that both parameters are required.

• `RAMP:CURRent?`

Returns the programmed current in units of amperes and the ramp rate in units of amperes/second or amperes/minute (per the selected ramp units). The two return values are separated by a comma. For example:

```
RAMP:CURRENT?
50.0000,0.1000
```

• `CONFigure:RAMP:FIELD` *<field (kG, T)>, <rate (kG/s, kG/min, T/s, T/min)>*

Sets both the programmed field in kilogauss or Tesla (per the selected field units), and the ramp rate in kilogauss/second, kilogauss/minute, Tesla/second, or Tesla/minute (per the selected field units and ramp units), with one command string. Note that both parameters are required. This command requires that a coil constant be defined, otherwise an error is generated.

• `RAMP:FIELD?`

Returns the programmed field in units of kilogauss or Tesla (per the selected field units) and the ramp rate in units of kilogauss/second, kilogauss/minute, Tesla/second, or Tesla/minute (per the selected field units and ramp units). The two return values are separated by a comma. This query requires that a coil constant be defined, otherwise an error is generated.

• `VOLTage:MAGnet?`

Returns the magnet voltage in volts. Requires voltage taps to be installed across the magnet terminals.

• `VOLTage:SUPPly?`

Returns the power supply voltage commanded by the Model 420 in volts.

• `CURRent:MAGnet?`

Returns the measured magnet (shunt) current in amperes.

- `FIELD:MAGnet?`

Returns the calculated field in kilogauss or Tesla, per the selected field units. This query requires that a coil constant be defined, otherwise an error is generated. The field is calculated by multiplying the measured shunt current by the coil constant.

4.5.5 Ramping State Commands and Queries

The ramping state commands control and query the ramping state of the Model 420. For more information regarding each state, see paragraph 3.3 on page 50.

If the ramping state is commanded remotely, the front panel display and switch LEDs will update and accurately reflect the commanded ramping state.

- `RAMP`

Places the Model 420 in the programmed ramping mode. The Model 420 will continue to ramp at the ramp rate until the programmed current/field is achieved.

- `PAUSE`

Pauses the Model 420 at the present operating current/field.

- `UP`

Places the Model 420 in the MANUAL UP ramping mode. Ramping continues at the ramp rate until the current limit is achieved.

- `DOWN`

Places the Model 420 in the MANUAL DOWN ramping mode. Ramping continues at the ramp rate until the current limit is achieved (or zero current is achieved for unipolar power supplies).

- `ZERO`

Places the Model 420 in ZEROING CURRENT mode. Ramping automatically initiates and continues at the ramp rate until the power supply output current is equal to 0 A.

• STATE?

Returns an integer value corresponding to the ramping state according to the table below:

Table 4-3. Return values and their meanings for the STATE? query.

Return Value	Meaning
1	RAMPING to programmed current/field
2	HOLDING at the programmed current/field
3	PAUSED
4	Ramping in MANUAL UP mode
5	Ramping in MANUAL DOWN mode
6	ZEROing current
7	Quench detected
8	Heating persistent switch

4.5.6 Switch Heater Commands and Queries

The PSwitch commands control and query the state of the persistent switch heater. For further information regarding the persistent switch heater, see paragraph 3.4 on page 56.

• PSwitch {0|1}

Turns the persistent switch heater OFF and ON. Sending "0" turns the switch heater OFF. Sending a "1" turns the switch heater ON. The default value is "0".

• PSwitch?

Returns a "0" indicating the switch heater is OFF, or a "1" indicating the persistent switch heater is ON.

4.5.7 Quench State Control and Queries

The QUench commands control and query the quench state of the Model 420. For further information regarding the quench detection functions, see paragraph 3.5 on page 58.

• QUench {0|1}

Clears or sets the quenched state. Sending a "0" clears any quench condition (equivalent to pressing the **RESET/ZERO** front panel switch). Send a "1" sets a quench condition. Setting the quench state to "1" is equivalent to a quench detection by the instrument, i.e. the power supply output is forced to 0 V, the quench output of the rear panel connector J4 is asserted, and all ramping functions are disabled.

- QUench?

Queries the quench state. If a "0" is returned, no quench condition exists. If a "1" is returned, a quench detect has occurred and is still in effect.

4.5.8 Trigger Functions

The Model 420 provides trigger functions which provide a means of collecting operational data with a minimum of commands and directing the output to either or both remote interfaces.

4.5.8.1 Description of the Trigger Functions

The Model 420 defines a *trigger enable register*, very similar to the enable registers of the status system, which controls which data is output and the interface to which the data is presented. The trigger enable register is defined as shown in Table 4-4.

Table 4-4. Bit definitions for the Model 420 trigger functions.

Bit Number	Decimal Value	Definition
0 Magnet Voltage	1	Magnet voltage in volts is included in trigger output.
1 Magnet Current	2	Magnet current in amperes is included in the trigger output.
2 Magnet Field	4	Magnet field in kilogauss or Tesla (per the selected field units) is included in the trigger output.
3 Time	8	The trigger time is included in the trigger output in the form *hh:mm:ss.ss*.
4 *Not Used*	16	*Reserved for future use.*
5 Formatted Output	32	The trigger output data is formatted.
6 Serial Interface	64	Trigger output data is placed in the serial interface output buffer and transmitted immediately.
7 IEEE-488 Interface	128	Trigger output data is placed in the IEEE-488 output buffer.

To enable the trigger functions, the *ETE <enable_value> command is written with a decimal value corresponding to the binary-weighted sum of the desired functions. Upon receipt of the low-level IEEE-488 bus trigger or the *TRG command, the Model 420 places the return data in the appropriate output buffer(s). Data placed in the serial interface buffer is transmitted immediately. Data placed in the IEEE-488 output buffer must be collected by the host device. Note that trigger output data may be placed in both the serial *and* the IEEE-488 output buffers if desired.

Note

Since trigger data is output immediately to the serial interface, it is possible to use the trigger functions to drive a terminal, modem, or a line printer (if a serial-to-parallel converter is available) connected to the serial interface.

If the trigger output data is not formatted, the data will be comma delimited and returned in the order of *time*, *magnet field*, *magnet current*, and *magnet voltage*. Only the data enabled for output will appear in the trigger output string.

4.5.8.2 Trigger Commands and Queries

- `*ETE` *<enable_value>*

Enables trigger functions according to the definitions in Table 4-4. To enable the trigger functions, you must write a decimal *<enable_value>* which corresponds to the binary-weighted sum of the functions you wish to enable. For example, to enable *formatted* output of the *time*, *magnet field*, and the *magnet voltage* to the serial interface, send the command:

```
*ETE 109;
```

The return data in the serial output buffer would appear as (with the field units selected as kilogauss):

```
00:03:14.85, FIELD=   20.002 kG, VOLTAGE=    2.05 V
```

- `*ETE?`

The `*ETE?` query returns a decimal sum which corresponds to the binary-weighted sum of the trigger functions enabled by the last `*ETE` command.

- `*TRG`

Initiates trigger output to the enabled interfaces for trigger functions.

4.6 Error Messages

If an error occurs, the Model 420 will beep, load the internal error buffer with the error code and description, and set the appropriate bits in the standard event and status byte registers if enabled by the user. Error codes are returned with a negative 3 digit integer, then a comma, and then a description enclosed in double quotes.

Use the `SYSTem:ERRor?` query to retrieve the errors in first-in-first-out (FIFO) order. Errors are removed from the internal error buffer as they are read. The Model 420 can store up to 10 errors.

If more than 10 errors have occurred, the last error stored in the internal error buffer is replaced with `-304,"Error buffer overflow"`. No additional errors are stored until you have cleared at least one error from the buffer. If no errors have occurred and the `SYSTem:ERRor?` query is sent to the Model 420, the instrument will return:

`0,"No errors"`

Error strings may contain up to 80 characters. Errors are classified in the following categories: *command errors*, *query errors*, *execution errors*, and *device errors*. Each category corresponds to the identically named bit in the standard event register (see page 66). If an error occurs in any one of the categories, the corresponding bit in the standard event register is set and remains set until cleared by the user.

4.6.1 Command Errors

`-101,"Unrecognized command"`

The command string sent was not identified as valid. Check the command string for invalid characters or separators, syntax errors, or for errors in the mnemonics. Spaces are not allowed before or after colon separators, and at least one space must separate a command string from the parameter(s).

`-102,"Invalid argument"`

The argument provided as a parameter for the command was invalid. *Value* arguments must be of the following form:

- an optional plus or minus sign,
- a sequence of decimal digits, possibly containing a single decimal point, and
- an optional exponent part, consisting of the letter `e` or `E`, an optional sign, and a sequence of decimal digits.

Enable_value arguments must be within the inclusive range of 0 to 255.

`-103,"Non-boolean argument"`

The command required a parameter in the form of 0 or 1. No other form of the parameter is allowed.

`-104,"Missing parameter"`

The command required at least one argument which was not found before the termination character(s).

`-105,"Out of range"`

At least one of the parameter values received was out of the valid range. Refer to the summary of valid ranges for the Model 420 settings on page 60. Be sure to note the field units and ramp units settings and check any unit conversions.

`-106,"Undefined coil const"`

The user attempted to invoke a command with units of field without first setting a value for the coil constant. The coil constant must be a non-zero, positive value.

`-107,"No switch installed"`

The user attempted to activate the persistent switch heater when no switch is installed. Before activating the persistent switch heater, the user must indicate a switch is installed and set the switch current and heating time (see page 44).

4.6.2 Query Errors

`-201,"Unrecognized query"`

The query string sent (identified as a query by a `?`) was not identified as valid. Check the query string for invalid characters or separators, syntax errors, or for errors in the mnemonics. Spaces are not allowed before or after colon separators.

`-202,"Undefined coil const"`

The user attempted to invoke a query with units of field without first setting a value for the coil constant. The coil constant must be a non-zero, positive value.

`-203,"Query interrupted"`

A new query was processed before the return string of a previous query had been completely transmitted to the host. The new query clears the remaining data and replaces it with the new return string.

4.6.3 Execution Errors

`-301,"Heating switch"`

The user attempted to initiate a ramping function during the persistent switch heating period. Ramping functions are disallowed during the heating period.

`-302,"Quench condition"`

The user attempted to change the ramping state while a quench condition is active. A quench condition must be cleared via the **RESET/ZERO** switch or by remote command before the ramping state can be modified.

`-303,"Input overflow"`

The four input buffers are all occupied with unprocessed commands or queries. The command or query is lost. Review the handshaking section on page 70 for directions for avoiding input overflow errors.

`-304,"Error buffer overflow"`

More than 10 errors have occurred. For further errors to be recorded in the internal buffer, at least one error must be cleared.

4.6.4 Device Errors

`-401,"Checksum failed"`

The non-volatile memory which stores the calibration data for the Model 420 is corrupted. Contact an Authorized AMI Technical Representative for further instructions. Do not continue to use the Model 420 to operate a superconducting magnet.

`-402,"Serial framing error"`

The baud rate of the Model 420 and host device are not identical. Both the Model 420 and host device must be set to the identical baud rate.

`-403,"Serial parity error"`

The number of data bits and/or the parity of the Model 420 and the host device are not identical.

`-404,"Serial data overrun"`

The received buffer of the Model 420 was overrun. Either switch to software handshaking (XON/XOFF), or decrease the baud rate.

5 Service

5.1 Model 420 Maintenance

The Model 420 was designed and manufactured to give years of reliable service. The only routine maintenance required is to keep the exterior surfaces of the instrument clean by gently wiping with a damp cloth moistened with a mild detergent.

5.2 Model 420 Troubleshooting Hints

The following paragraphs serve as an aid to assist the user in troubleshooting a potential problem with the Model 420 within a superconducting magnet system. If the user is not comfortable in troubleshooting the system, you may contact an AMI Technical Support Representative for assistance. Refer to "Additional Technical Support" on page 99.

This instrument contains CMOS components which are susceptible to damage by Electrostatic Discharge (ESD). Take the following precautions whenever the cover of the instrument is removed.

1. Disassemble the instrument only in a static-free work area.
2. Use a conductive workstation or work area to dissipate static charge.
3. Use a high resistance grounding wrist strap to reduce static charge accumulation.
4. Ensure all plastic, paper, vinyl, Styrofoam® and other static generating materials are kept away from the work area.
5. Minimize the handling of the instrument and all static sensitive components.
6. Keep replacement parts in static-free packaging.
7. Do not slide static-sensitive devices over any surface.
8. Use only antistatic type solder suckers.
9. Use only grounded-tip soldering irons.

5.2.1 The Model 420 does not appear to be energized with the power switch in the POWER (I) position.

1. Ensure that the Model 420 is energized from a power source of proper voltage.

Warning

If the instrument has been found to have been connected to an incorrect power source, return the instrument to AMI for evaluation to determine the extent of the damage. Frequently, damage of this kind is not visible and must be determined using test equipment. Connecting the instrument to an incorrect power source could damage the internal insulation and/or the ground conductors, thereby, possibly presenting a severe life-threatening electrical hazard.

2. Verify continuity of the line fuse, F1, located on the instrument printed circuit board.

Warning

This procedure is to be performed only when the instrument is completely de-energized by removing the power-cord from the power receptacle. Failure to do so could result in personnel coming in contact with high voltages capable of producing life-threatening electrical shock.

   a. Ensure the instrument is de-energized by disconnecting the power cord from the power source. Disconnect the power cord from the connector located on the rear panel of the instrument.

   b. Remove the instrument top cover and check the fuse F1 for continuity.

   c. If the fuse is bad, replace with a fuse of identical rating.

Caution

Installing fuses of incorrect values and ratings could result in damage to the instrument in the event of component failure.

Note

The proper fuse for this instrument is an IEC Type F, 5x20mm fuse rated for 0.315 Amperes, quick acting. The fuse will be labeled with the current rating and marked with an F, or red color code to denote quick acting.

d. Replace the fuse and securely fasten the instrument top cover. Reconnect the power-cord.

3. Verify the input voltage selector switch on the instrument's printed circuit board is in the proper position for the available input power. Checking the input voltage selector requires removal of the top cover of the instrument. Observe the same safety procedures as presented in step 2, above.

5.2.2 The Model 420 does not remember the operating setpoints after power is removed.

Warning

This procedure is to be performed only when the instrument is completely de-energized by removing the power-cord from the power receptacle. Failure to do so could result in personnel coming in contact with high voltages capable of producing life-threatening electrical shock.

1. Ensure the instrument is de-energized by disconnecting the power cord from the power source. Disconnect the power cord from the connector located on the rear panel of the instrument.

2. Remove the instrument top cover and replace the computer memory backup battery, BT1.

Note

When replacing the battery, replace with a 3.6 volt AA-size lithium cell (International size reference: ER14505). Comply with the polarity markings adjacent to the battery holder on the printed wiring board.

Warning

Do not attempt to recharge the Lithium cell. Attempts at recharging may cause the cell to vent or explode.

5.2.3 The power supply is unstable, causing the magnet current to oscillate.

1. Verify the power supply is configured for remote programming, voltage-to-voltage mode. Consult the manufacturer's operations manual for the necessary power supply configuration.

2. Verify that the persistent switch heater is operating. Also, verify that the actual persistent switch in the magnet is correctly installed and connected.

Note

If the persistent switch heater is activated without an inductive load present at the supply outputs, oscillating current will result. The Model 420 is designed to operate large inductive loads with only relatively small resistive characteristics (i.e. superconducting magnets). The Model 420 is not designed for use as a general purpose power supply controller for resistive loads.

3. If the magnet has no persistent switch installed, or has a small inductance (typically less than 1 Henry), then adjust the stability setting for the Model 420. As this setting is increased, the system should become more stable. For best results, minimize the amount that this value is adjusted from 0.0%. Refer to paragraph 3.2.2.1 on page 42.

5.2.4 The power supply system will not charge the magnet.

1. Verify system interconnecting wiring. Refer to paragraph 2.5 on page 15. If the Model 420 shows "*+0.00 A ↑ Status: Ramping*" with the supply voltage, *Vs*, increasing or at the programmed voltage limit (as indicated by the **VOLTAGE LIMIT** LED), there may be a problem with the power supply. Verify the power supply is on and the program out connection from the Model 420 to the program voltage input to the power supply is intact.

2. Verify the power supply is configured for remote programming, voltage-to-voltage mode. Consult the manufacturer's operations manual for the necessary power supply configuration.

3. Ensure the Model 610/630 Energy Absorber / Reversing Switch control unit is energized. By default, lack of power at the Model 610/630 causes a contact to shut which crowbars the power supply downstream of the Model 420 shunt.

5.2.5 The Model 420 will not charge the magnet at the selected RAMP RATE.

1. Ensure the Model 420 is properly configured for the connected power supply. See paragraph 3.2.1 on page 38.

2. Ensure that the persistent switch heater is on and the switch heating time has expired. Ramping is disabled during the switch heating period.

3. Check the value of the voltage limit. Refer to paragraph 3.3.1.1 on page 51.

Note

If an energy absorber is present in the system, the Model 420 must command enough power supply voltage to overcome any forward voltage drop due to the energy absorber. Increase the voltage limits to account for the energy absorber voltage drop.

4. Check for excessive wiring resistances in the magnet-power supply loop which may prevent proper charge/discharge voltages at the magnet. Use the local voltmeter on the power supply to see if the proper voltages exist across the various components in the magnet power loop. Loose or iced interconnections often exhibit excessive resistances.

5.2.6 The Model 420 will not discharge the magnet at the selected RAMP RATE.

Note

Rapid discharging of the magnet requires either an energy absorbing component or a four-quadrant power supply. If a unipolar supply is used without an energy absorbing component, only the resistance of the power leads is available as a mechanism for discharging the magnet.

1. Ensure that the persistent switch heater is on and the switch heating time has expired. Ramping is disabled during the switch heating period.

2. Check the value of the voltage limit. Refer to paragraph 3.3.1.1 on page 51.

3. For *unipolar power supply systems*, an energy absorber is usually required to ramp a magnet down in a reasonable amount of time. When ramping the system down at the fastest rate achievable, observe the voltage appearing at the power supply output terminals either by a voltmeter on the front of the supply or by a DVM measurement. If the supply output voltage is approximately zero, the resistance of the power leads (not the Model 420) is dictating the maximum ramp down rate. An energy absorber is necessary to increase the rampdown rate.

5.2.7 The Model 420 will not charge the magnet to desired field.

1. If the power supply ramps to full output current after the supply output voltage exceeds approximately 0.7 V, verify the polarity of the power supply protective diode. **Ensure the protective diode remains installed** across the output terminals of the power supply with the anode at the **NEG**ative terminal and the cathode at the **POS**itive terminal.

2. Ensure the voltage and current adjust controls on the front of the power supplies are in their fully clockwise position. Refer to the operations manual for the specific power supply for more information regarding the adjustment of the manual voltage and current controls when the supply is remotely programmed.

3. Ensure that the Model 420 supply setup submenu is configured to match the connected power supply, e.g. check that the Model 420 is configured for the proper voltage-to-voltage programming range according to paragraph 3.2.1.6 on page 41.

5.2.8 The four quadrant power supply will only supply current in one direction

1. Ensure the Model 420 is configured to allow negative power supply voltages according to paragraph 3.2.1.2 on page 40 and negative power supply currents according to paragraph 3.2.1.4 on page 40.

2. Verify that the Model 420 is configured for the proper voltage-to-voltage programming range according to paragraph 3.2.1.6 on page 41.

5.2.9 The Model 420 will not place the magnet in persistent mode.

1. Ensure there is adequate LHe level in the cryostat to allow the persistent switch to cool to the superconducting state.

5.2.10 The Model 420 will not bring the magnet out of persistent mode.

1. Check the continuity between the persistent switch heater power supply output pins on J7A or J7B and the connector on the magnet support stand top plate. Refer to Table A-1 on page 101.

2. Verify that the output of the persistent switch heater power supply is set to the appropriate value. Refer to paragraphs 3.2.2.5 and Figure 3-5 on page 48.

3. Ensure that there is sufficient time for the switch to warm before the power supply current is changed.

5.2.11 The magnet quenches for no apparent reason.

1. Ensure the magnet is not being charged at a **RAMP RATE** exceeding the capabilities of the magnet. Exceeding the designed rate for ramping the magnet may cause a quench or it may turn on protective diodes on the magnet which may appear very similar to a quench.

2. Ensure there is adequate LHe level in the cryostat. For systems operating at less then 4.2K, ensure the magnet is cooled to the temperature specified by the magnet manufacturer.

3. Disable the Model 420 quench detection feature (see paragraph 3.5.1 on page 59) if you suspect the Model 420 is falsely indicating a quench condition.

5.2.12 The Model 420 will not lower the field in the magnet.

1. Ensure the magnet is not in the persistent mode. Refer to paragraph 3.4.2 on page 57 for the procedure to remove a magnet from the persistent mode of operation.

2. Ensure the current from the persistent switch heater power supply in the Model 420 is reaching the switch heater. Check continuity between J7A or J7B on the Model 420 rear panel and the magnet support stand top plate electrical connector. Refer to Table A-1 on page 101.

5.2.13 There is excessive LHe boil-off during operation.

Excessive LHe consumption is usually attributable to two things: thermal energy being conducted into the cryostat or electrical energy being converted into thermal energy within the cryostat. Analyzing the circumstances under which the high boil-off occurs will help determine what is causing the problem.

1. For magnets equipped with switches for persistent operation, verify that the persistent switch heater power supply is operating at the proper current for the installed switch. Excessive currents cause excessive boiloffs. The typical switch requires approximately 45 mA to function correctly. Refer to the documentation provided with the magnet for proper operating current. See Figure 3-5 on page 48.

2. Verify that the protective diodes on the magnet are not turning on. Damaged diodes may short causing current to flow through them whenever magnet current flows and cause excessive heating. This can be identified by observing a change in the apparent field-to-current ratio since some of the current is bypassing the coil. If the boil off rate returns to normal with the magnet de-energized, this may indicate a defective diode.

3. Ensure that there are no inadvertent thermal paths between the cryogenic environment and the 300K environment. Ensure all transfer lines are removed from the cryostat; check the position of break-away vapor-cooled current leads.

4. Ensure the LHe level sensor is not continuously energized if continuous level indication is not necessary.

5. Ensure the vacuum in vacuum-jacketed dewars is of sufficiently low pressure.

5.2.14 The Model 420 will not display the magnetic field strength, only magnet current

1. Enter a coil constant in accordance with paragraph 3.2.2.2 on page 42.

   Note

   Setup menu limits are always required in terms of current.

5.2.15 The Model 420 is not responding to remote communications commands.

1. Verify your communications cable integrity and wiring. See the *Appendix* for DB-25 to DB-9 translation for RS-232 cables.

2. Check to make sure you are sending the correct termination to the instrument. If you are using RS-232 or the RS-422 option, make sure the baud rate, number of stop bits, and data bits/parity settings match the setting of the host device. If you are using the IEEE-488 option, check the primary address setting and make sure the controller software is set to query the instrument at the primary address selected.

3. Check your host communications software and make sure it is recognizing the return termination characters from the instrument. For RS-232 communication, the return termination characters are *<CR><LF>*. For IEEE-488, the return message termination characters are *<LF>* with EOI.

4. If the instrument is responding repeatedly with errors, try a device clear command (DCL) or powering the instrument off and then back on. Be sure you are sending valid commands.

If you experience continued trouble with the IEEE-488 interface, you may have an incompatible IEEE-488 card in your host computer. In the past, AMI has found subtle differences between manufacturers of IEEE-488 cards that have introduced communication errors. AMI attempts to establish compatibility with as many products as possible, however it is difficult to test every card available. Contact AMI directly if you have thoroughly checked your setup and continue to experience problems with the IEEE-488 interface.

5.3 Additional Technical Support

If the cause of the problem cannot be located, contact an AMI Technical Support Representative at (865) 482-1056 for assistance. The AMI technical support group may also be reached by Internet e-mail at **support@americanmagnetics.com**. Additional technical information, latest software releases, etc. are available at the AMI World Wide Web site at:

http://www.americanmagnetics.com

Do not return the Model 420 or other magnet system components to AMI without prior return authorization.

5.4 Return Authorization

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive proper attention. Please call an AMI representative at (865) 482-1056 for a return authorization number before shipping any item back to the factory.

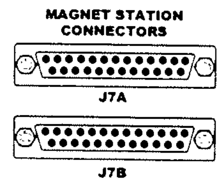
	Room T	77 °K	4.2 °K
Leads	22.8	18.4	
Switch Heater	73	70.2	

Precision Cryogenic Systems, Inc.
AMERICAN MAGNETICS, INC.
P.O.#: 28193/M9087
P.C.S.: PCS-079-01
S/N: 10-01-0327
PNS-2.36/10

	PIN		FUNCTION	
Liquid He level meter #2	A	(LS)	I+	
	B		I-	
	C		V-	
	D		V+	
Switch Heater	J	(PSH)	I+	71.8 Ω Cryostat @ RT
	K		I-	
Mag "tap" voltage	L	(MV)	V+	
	M		V-	
Liquid He level meter	N	(LS)	I+	
	P		I-	
	R		V-	
	S		V+	
	T	(SC)	I+	
	U		I-	

Appendix

A.1 Magnet Station Connectors



Connector @ cryostat

Table A-1. Connectors J7A and J7B pin definitions.

Go to LHe connectors J8A & J8B

Pin	Function	Pin	Function
A 1	LHe Sensor I+ (Red)	P 14	Spare LHe Sensor
B 2	LHe Sensor I– (Black)	R 15	Spare "
C 3	LHe Sensor V– (Yellow)	S 16	Spare "
D 4	LHe Sensor V+ (Blue)	T 17	~~Spare~~ Shim coil
5	~~Temperature Sensor I+ (Red)~~ N/C	U 18	~~External Switch Heater Current~~[a] "
6	~~Temperature Sensor I– (Black)~~ N/C	19	~~External Switch Heater Current~~ N/C
7	~~Temperature Sensor V– (Yellow)~~ N/C	20	Spare
8	~~Temperature Sensor V+ (Blue)~~ N/C	21	Spare
J 9	Persistent Switch Heater (Red)	22	Spare
K 10	Persistent Switch Heater (Black)	23	Spare
L 11	Magnet Voltage Tap V+ (Yellow)	24	Spare
M 12	Magnet Voltage Tap V– (Blue)	25	Spare
N 13	Spare LHe Sensor		

443 Ω (pins 1–2); 441. Ω (pins 14–16); 27.7 Ω (pins 17–18); 73 Ω (pins 9–10); 25.2 Ω (pins 11–12); 446 Ω to pin 14 (pin 13)

a. See discussion on page 58 for further details on the use of an optional external power supply for heating the persistent switch.

The two 25-pin D-sub female Magnet Station Connectors are identically wired and connected pin-for-pin internally. Spare wires may be used for custom coil taps or other signals.

The connectors provide an interface for connecting a *single* integrated instrumentation cable from the magnet support stand to the Model 420. The Model 420 can then be used to distribute the signals to the appropriate instruments or data acquisition systems. The LHe level and temperature sensor signals are also internally routed to the Auxiliary LHe Level/Temperature connectors J8A and J8B.

If the Model 420 is purchased as part of a magnet system, a Magnet Station Connector instrumentation cable will be provided with the system.

Note

For maximum noise immunity, use shielded cabling and connect one end of the shield to the J7A or J7B connector shell.

A.2 Auxiliary LHe Level/Temperature Connectors

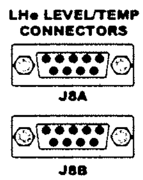


Table A-2. Connectors J8A and J8B pin definitions.

Go To Pins 5, 6, 7, & 8 on J7A & J7B

Pin	Function
1	LHe Sensor I+ (Red)
2	~~Temperature Sensor I+ (Red)~~
3	~~Temperature Sensor V− (Yellow)~~
4	~~Temperature Sensor I− (Black)~~
5	~~Temperature Sensor V+ (Blue)~~
6	LHe Sensor V− (Yellow)
7	LHe Sensor I− (Black)
8	LHe Sensor V+ (Blue)
9	*Not Used*

The two 9-pin D-sub male Auxiliary LHe Level and Temperature connectors are identically wired and connected pin-for-pin internally.

The connectors route the incoming signals from the Magnet Station Connectors to external level and/or temperature instruments. If an AMI Liquid Helium Level Instrument is purchased with the Model 420 and magnet system, an LHe level cable will be provided.

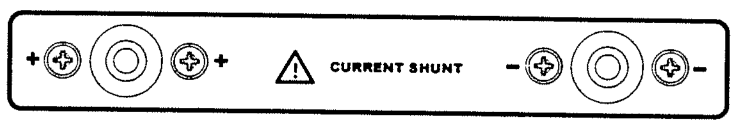
Warning

Although the LHe level sensor connector terminals are isolated from earth ground and therefore touching one terminal is not hazardous, the voltage between terminals is at a hazardous potential if an AMI Liquid Helium Level Instrument is connected and energized. The LHe level sensor pins are designed for use with an AMI LHe sensor and the wiring for the sensor is to have no live parts which are accessible. Conductors connected to its terminals must be insulated from user contact by basic insulation rated for 150 VAC (Category I).

Note

For maximum noise immunity, use shielded cabling and connect one end of the shield to the J8A or J8B connector shell.

A.3 Current Shunt Terminals

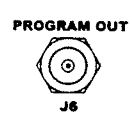


The Current Shunt Terminals should be connected so that positive direction current flows from the + terminal to the – terminal. Refer to the diagrams in the *Installation* section (page 13) for detailed descriptions of the system interconnections.

Warning

Exercise caution near the shunt terminals when operating a magnet. Metallic objects shorted across the shunt terminals may conduct large DC currents which are capable of melting the object and causing severe burns.

A.4 Program Out BNC Connector



The Program Out female BNC connector provides up to a –10 VDC to +10 VDC output designed to drive the remote *voltage-to-voltage* programming input of a connected power supply. Refer to the *Installation* section for detailed descriptions of the system interconnections, or refer to the manual for your power supply. The coaxial shield is the output return. The center conductor is the program out voltage.

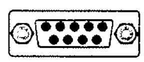
Note

For maximum noise immunity, the Model 420 chassis and the chassis of any connected power supply should be tightly electrically coupled. This can be accomplished through the rack mounting or by using a grounding strap between the chassis.

Note

Do not connect J6 to the Model 601 rear-panel coaxial connector.

A.5 Quench I/O Connector



Connector J4 provides pins for quench detection input, quench detection output signals, and optional switching of an external persistent switch heater power supply. The shell lugs of the connector are connected to the Model 420 chassis ground. J4 is a 9-pin D-sub female connector.

Table A-3. Connector J4 pin definitions.

Pin	Function
1	Quench Output +
2	Quench Output –
3	Ground
4	Optional External Power Supply[a]
5	Optional External Power Supply
6	Quench Input +
7	Quench Input –
8	+5 VDC
9	Spare TTL Output

a. See discussion on page 58 for further details on the use of an optional external power supply for heating the persistent switch.

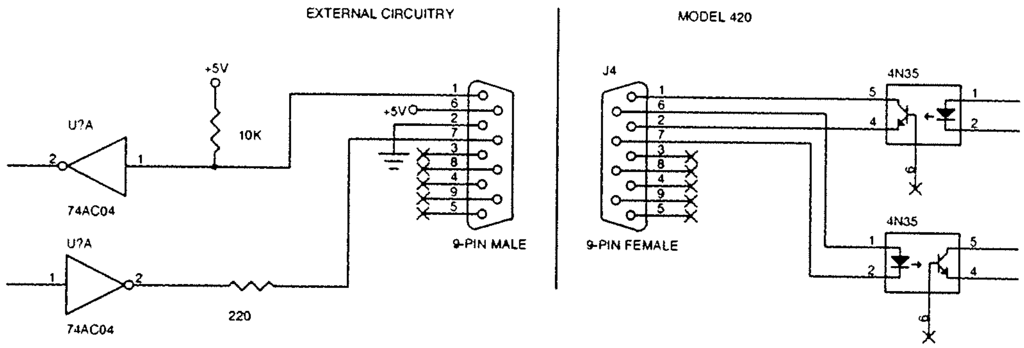


Figure A-1. Example external circuitry for quench input/output.

Quench External Input (4N35 optocoupler input):

Maximum optocoupler input LED forward voltage @ 10mA (V_f, across rated temperature)	1.7V
Minimum on-state optocoupler input LED forward current (I_f, across rated temperature)	10mA
Maximum off-state optocoupler input LED forward current (I_f, across rated temperature)	10μA
Maximum allowable optocoupler input LED forward current (I_f, across rated temperature)	30mA
Maximum allowable optocoupler input LED reverse voltage (V_r, across rated temperature)	6V
Galvanic isolation voltage from quench external input to earth ground	500VDC

Quench External Output (4N35 optocoupler output):

Maximum on-state optocoupler output saturation voltage @ 0.5 mA out ($V_{ce\text{-}sat}$, across rated temp.)	0.35V
Maximum off-state optocoupler output leakage current (I_{ceo}, across rated temperature)	2.5μA
Maximum allowable off-state optocoupler output voltage (V_{ceo}, across rated temperature)	30V
Maximum allowable optocoupler output reverse voltage (V_{eco}, across rated temperature)	7V
Galvanic isolation voltage from quench external output to earth ground	500VDC

A.6 IEEE-488 Connector

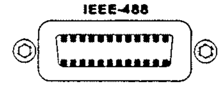


Table A-4. IEEE-488 female connector J11 description.

Pin	Mnemonic	Description
1	DIO1	Data In/Out Bit 1
2	DIO2	Data In/Out Bit 2
3	DIO3	Data In/Out Bit 3
4	DIO4	Data In/Out Bit 4
5	EOI	End or Identify
6	DAV	Data Valid
7	NRFD	Not Ready for Data
8	NDAC	Not Data Accepted
9	IFC	Interface Clear
10	SRQ	Service Request
11	ATN	Attention
12	SHIELD	Cable Shield (connected to 420 chassis gnd)
13	DIO5	Data In/Out Bit 5
14	DIO6	Data In/Out Bit 6
15	DIO7	Data In/Out Bit 7
16	DIO8	Data In/Out Bit 8
17	REN	Remote Enable
18	GND	Ground, Twisted pair with DAV
19	GND	Ground, Twisted Pair with NRFD
20	GND	Ground, Twisted Pair with NDAC
21	GND	Ground, Twisted Pair with IFC
22	GND	Ground, Twisted Pair with SRQ
23	GND	Ground, Twisted Pair with ATN
24	SGND	Signal Ground

A.7 RS-232/422 Connector

J12 is a 25-pin D-sub female connector.

Table A-5. PC-to-Model 420 connections for **RS-232 operation.**

PC (DTE) DB-25 Pin	**Model 420 (DCE)** DB-25 Pin	**DTE Function**
2	2	TD
3	3	RD
4	4	RTS
5	5	CTS
6	6	DSR
7	7	GND
8	8	DCD
20	20	DTR
22	22	RI

Table A-6. PC (DB-9)-to-Model 420 connections for **RS-232 operation.**

PC (DTE) DB-9 Pin	**Model 420 (DCE)** DB-25 Pin	**DTE Function**
3	2	TD
2	3	RD
7	4	RTS
8	5	CTS
6	6	DSR
5	7	GND
1	8	DCD
4	20	DTR
9	22	RI

Pin 1 of connector J12 is also connected to the Model 420 chassis ground.

Table A-7. EIA-530 Device-to-Model 420 connections for **RS-422 operation.**

EIA-530 Device (DTE) DB-25 Pin	**Model 420 (DCE)** DB-25 Pin	**DTE Function**
2	21	TX–
3	16	RX–
4	12	RTS–
5	13	CTS–
6	11	DSR–
7	7	GND
8	14	DCD–
10	8	DCD+
13	5	CTS+
14	2	TX+
16	3	RX+
19	4	RTS+
20	15	DTR–
22	6	DSR+
23	20	DTR+

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CE

Declaration of Conformity

Application of Council Directive:	72/73/EEC
Standard to which Conformity is Declared:	EN 61010-1: 1993 w/A1, A2
Manufacturer's Name:	American Magnetics, Inc.
Manufacturer's Address:	112 Flint Road, P.O. Box 2509 Oak Ridge, TN 37831-2509 U.S.A.
Type of Equipment:	Liquid Level Instruments
Model Numbers:	Model 185 and 186

I, the undersigned, hereby declare that the equipment specified above conforms to the above Directive and Standard.

Place:	Oak Ridge, Tennessee, U.S.A.	Signature:	Charles Hargis
Date:	October 15, 1999	Full Name:	Charles H. Hargis
		Function:	Quality Assurance Manager

Supplier:
Permatex, Inc.
10 Columbus Blvd.
Hartford, CT 06106
Telephone: 1-87-Permatex
(877) 376-2839

Material Safety Data Sheet

1. PRODUCT IDENTIFICATION

Product Name: 67V DIELECTRIC TUNE-UP GREASE
Item No: 81150
Product Type: Lubricant

2. COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients	Percent	ACGIH 8 Hr. TWA:	OSHA 8 Hr. TWA:
POLYDIMETHYLSILOXANE 63148-62-9	75-85		
AMORPHOUS SILICA 7631-86-9	15-25	10 mg/m3 TWA	6 mg/m3 TWA

3. HAZARDS IDENTIFICATION

Toxicity: May cause eye and skin irritation.
Primary Routes of Entry: Eye and skin contact, ingestion, inhalation.
Signs and Symptoms of Exposure: Overexposure may cause eye and skin redness.

Medical Conditions Recognized as Being Aggravated by Exposure: None known

4. FIRST AID MEASURES

Ingestion: If swallowed, DO NOT induce vomiting. Keep individual calm. Obtain medical attention.
Inhalation: If inhaled, remove from area to fresh air. Get medical attention if respiratory irritation develops or if breathing becomes difficult.
Skin Contact: Wash with soap and water. Seek medical attention if irritation persists.
Eye Contact: In case of contact, immediately flush eyes with plenty of water for at least 15 minutes and get medical attention if irritation persists.

5. FIRE FIGHTING MEASURES

Flash Point (°F/C): Greater than 575 degrees F. Method: Tag Closed Cup
Recommended Extinguishing Media: Carbon Dioxide, Dry Chemicals, Foam.
Special Fire-Fighting Procedures: No special procedures.
Hazardous Products Formed by Fire or Thermal Decomposition: None anticipated
Unusual Fire/Explosion Hazards: None
Lower Explosive Limit: Not determined
Upper Explosive Limit: Not determined

6. ACCIDENTAL RELEASE MEASURES

Spill Procedures: Maintain good ventilation. Take up with an inert absorbent. Store in a closed waste container until disposal. Clean up spills thoroughly as residue is slippery.

7. HANDLING AND STORAGE

Storage: No special precautions.
Handling: Avoid prolonged skin contact. Keep away from eyes.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Eyes:	Safety glasses or goggles.
Skin:	Rubber or plastic gloves
Ventilation:	General ventilation is usually adequate.
Respiratory Protection:	Not normally necessary.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	White, translucent grease
Odor:	Slight hydrocarbon odor.
Boiling Point (°F):	Not determined.
pH:	Does not apply
Solubility in Water:	Nil
Specific Gravity:	1.03
VOC Content(Wt.%):	0.4% by weight; 4.1 g/l
Vapor Pressure:	Not Determined
Vapor Density (Air=1):	Not Determined
Evaporation Rate:	Not determined

10. STABILITY AND REACTIVITY

Chemical Stability:	Stable at normal conditions
Hazardous Polymerization:	WILL NOT OCCUR
Incompatabilities:	None known
Conditions to Avoid:	None anticipated
Hazardous Products Formed by Fire or Thermal Decomposition:	None anticipated

11. TOXICOLOGICAL INFORMATION

See Section 3

12. ECOLOGICAL INFORMATION

No data available

13. DISPOSAL CONSIDERATIONS

Recommended Method of Disposal:	Disposal should be made in accordance with federal, state and local regulations.
US EPA Waste Number:	NH - Not a RCRA Hazardous Waste Material

14. TRANSPORT INFORMATION

DOT (49CFR 172)

Domestic Ground Transport

DOT Shipping Name:	Unrestricted
Hazard Class:	NONE
UN/ID Number:	None
Marine Pollutant:	None

IATA

Proper Shipping Name:	Unrestricted
Class or Division:	None
UN/NA Number:	NONE

IMDG

Proper Shipping:	Unrestricted
Hazard Class:	None
UN Number:	None

15. REGULATORY INFORMATION

SARA 313 Chemicals: The following component(s) is listed as a SARA Section 313 Toxic Chemical
NONE

CALIFORNIA PROP 65:

Product Name:	**67V DIELECTRIC TUNE-UP GREASE**
Item No:	**81150**

No California Prop 65 chemicals are known to be present.

TSCA Inventory Status:
All components of this product are listed (or exempt) on the EPA TSCA inventory.

16. OTHER INFORMATION

Estimated NFPA Rating:	HEALTH 1, FLAMMABILITY 1 , REACTIVITY 0
Estimated HMIS Classification:	FLAMMABILITY 1 , REACTIVITY 0 , HEALTH 1

NFPA is a registered trademark of the National Fire Protection Assn.
HMIS is a registered trademark of the National Paint and Coatings Assn.

Prepared By:	**Denise Boyd**	**Health and Safety Manager**
Company:	**Permatex. Inc.**	**10 Columbus Blvd. Hartford, CT 06106**
Telephone Number:	**1-87-Permatex**	**(877) 376-2839**
Revision Date:		03/07/2001

IMPORTANT CALIBRATION INFORMATION.

PLEASE READ BEFORE INSTALLATION AND OPERATION OF THIS INSTRUMENT.

American Magnetics, Inc. (AMI) only has Liquid Nitrogen on-site for calibration of liquid-level instruments and sensors. Because we manufacture custom sensors of various shapes and sizes, we are not always able to submerge the full length of the liquid-level sensor.

The checked box below indicates how your system was calibrated.

- [x] This system was purchased for operation in liquid nitrogen (LN2) at atmospheric pressure, and the system was calibrated accordingly.
- [ ] Due to pressure, liquid, and/or sensor length specifications of your system, an approximate calibration was performed. Please refer to the section on Approximate Calibration in the manual.
- [ ] Due to the specifications of your system, no calibration was performed by American Magnetics.

American Magnetics, Inc.

P.O. Box 2509, 112 Flint Road, Oak Ridge, TN 37831-2509
Phone: (865) 482-1056 Fax: (865) 482-5472
Internet: http://www.americanmagnetics.com E-mail: sales@americanmagnetics.com

AMI LIQUID LEVEL SENSOR

(INCLUDING OSCILLATOR AND CABLES)

INSTALLATION, OPERATION AND MAINTENANCE INSTRUCTIONS

I. INTRODUCTION

The AMI liquid level sensor is a cylindrical capacitor constructed of stainless steel which allows a cryogenic fluid to become the dielectric between the concentric plates. The instrument measures the sensor capacitance which is directly related to the percentage of the sensor immersed in the cryogenic liquid.

II. SPECIFICATIONS

Diameter	0.375" (Standard)
Active lengths	Typically up to 255.9 inches (650 cm)
Overall length	Up to 20 feet (longer multi-section lengths available upon request)
Resistance	> than 10 Meg ohms (with no liquid level)

III. INSTALLATION

A. Carefully remove the sensor from the shipping container and remove all packaging material.

> *If there is any shipping damage, save all packing material and contact the shipping representative to file a damage claim. Do not return the instrument to AMI unless prior authorization has been received.*

B. Install the sensor in the vessel using the specified fitting of the sensor.

> *CAUTION: Ensure the sensor is mounted with the top vent hole located inside of the cryostat.*

> *NOTE: Avoid installing in a location where icing may occur. Ice formations or moisture buildup on the BNC connector*

may cause the sensor to short out indicating a higher liquid level than actually exists.

<u>CAUTION</u>: Exercise care when installing the sensor since dents, crimps, bends or other physical distortions in the thin wall capacitor will change electrical characteristics possibly causing calibration errors and/or disruption of proper instrument operation. Before installing the sensor, the user may want to review the Calibration and Operation sections of the meter manual to determine what, if any, calibration procedures may be necessary.

C. Connect the oscillator to the sensor using a supplied 6 foot RG-59/U coaxial cable. Ensure the oscillator is connected in the correct orientation (see figure). The cable length between the oscillator and the sensor should not exceed 6 feet.

<u>CAUTION</u>: The coaxial interconnecting cables and the oscillator are temperature sensitive and should be mounted in such a manner as to avoid large temperature changes such as those encountered in the path of dewar vents.

<u>CAUTION</u> : Moisture or contaminants in any of the BNC coaxial connectors can short out the sensor and cause a false 'full' level indication or other erroneous readings. A pack of non-conductive Electrical Connection Lubricant (ECL), also called Dielectric Tune-up Grease, has been included with the liquid level sensor packaging to use to reduce the possibility of this occurring. Apply a small amount of ECL to the mating contacts of any of the BNC connectors that may be exposed to moisture (typically the BNC connection at the end of the sensor). Mate the doped connectors; then apply ECL to the exterior of the mated BNC connectors. Spread the ECL around the entire exterior of the BNC connectors, working the ECL into all connector and coaxial cable seams. Cover the doped connections with the supplied short section of heat-shrink tubing, and shrink with a heat-shrink heat gun. (If you do not have a heat-shrink gun, any device that will heat the tubing to between 90°- 125°C will work).

Note: MSDS sheets for the ECL are available upon request. To request MSDS sheet, ask for AMI part # MS-1910.

IV. MAINTENANCE

The liquid level sensor will provide years of useful service and require no maintenance if installed and operated in accordance with these instructions.

V. TROUBLESHOOTING

A. No level reading (indicated on the level instrument):

Ensure the orientation of the oscillator assembly is correct.

B. Erratic or erroneous level reading (indicated on the level instrument):

1. Verify that the sensor is properly connected to the oscillator cable and the extension cable (see figure).

2. Ensure the oscillator unit is not exposed to large temperature changes such as near dewar vents. Severe temperature changes of the oscillator unit can cause readout errors.

3. Verify the sensor is free of contaminants and not subject to any physical distortion. Disconnect the BNC connector at the top of the sensor and measure the sensor resistance by placing an ohmmeter across the center pin and the outer barrel of the connector. The resistance of the sensor should typically be >10 Meg ohms.

4. Ensure there is no ice formations or moisture buildup at the top of the sensor.

If the level instrument suddenly reads 100% without a corresponding level, there is a possibility of moisture in the connector at the top of the sensor. Disconnect the BNC connection and remove any moisture. Moisture or contaminants in any of the BNC coaxial connectors can short out the sensor and cause a false 'full' level indication or other erroneous readings. A pack of non-conductive Electrical Connection Lubricant (ECL), also called Dielectric Tune-up Grease, has been included with the liquid level sensor packaging to use to reduce the possibility of this occurring. Apply a small amount of ECL to the mating contacts of any of the BNC connectors that may be exposed to moisture (typically the BNC connection at the end of the sensor). Mate the doped connectors; then apply ECL to the exterior of the mated BNC connectors. Spread the ECL around the entire exterior of the BNC connectors, working the ECL into all connector and coaxial cable seams. Cover the doped connections with the supplied short section of heat-shrink tubing, and shrink with a heat-shrink heat *gun. (If you do not have a heat-shrink gun, any device that will heat the tubing to between 90°- 125°C will work).*

Note: MSDS sheets for the ECL are available upon request. To request MSDS sheet, ask for AMI part # MS-1910.

5. Ensure the sensor has no condensation or debris between the inner and outer tubing.

6. Verify the cabling has no breaks or cuts.

7. Rapidly varying or sloshing liquids will sometimes make one think the instrument is in error when it is actually operating properly.

C. In the event you are unable to locate the problem or have additional question, please call an AMI representative at (865) 482-1056.

VI. WARRANTY

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of a failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. All warranty repairs are F.O.B. Oak Ridge, Tennessee.

VII. RETURN AUTHORIZATION

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive the proper attention. Please call an AMI representative at (865) 482-1056 for a return authorization before shipping any item back to us.

EXCELLENCE IN MAGNETICS AND CRYOGENICS

MODEL 185/186 LIQUID LEVEL INSTRUMENT

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

American Magnetics, Inc.

PO Box 2509, 112 Flint Road, Oak Ridge, TN 37831-2509, Tel: 865 482-1056, Fax: 865 482-5472

Rev. 2, October 2000

Model 185/186 Liquid Level Instrument

Instrument Configuration

AMI Order Number: TR 146844

Shipping Date: ________

Model/Serial #: 186CE/01-1206-1

Firmware Revision: n1 3.3

Input Power Requirements: 120VAC

Configuration Notes:

CALIBRATED WITH OSCILLATOR 01-1206-2 AND SENSOR 01-1206-3.

AMI Warranty

All products manufactured by AMI are warranted to be free of defects in materials and workmanship and to perform as specified for a period of one year from date of shipment. In the event of failure occurring during normal use, AMI, at its option, will repair or replace all products or components that fail under warranty, and such repair or replacement shall constitute a fulfillment of all AMI liabilities with respect to its products. Since, however, AMI does not have control over the installation conditions or the use to which its products are put, no warranty can be made of fitness for a particular purpose, and AMI cannot be liable for special or consequential damages. All warranty repairs are F.O.B. Oak Ridge, Tennessee, USA.

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Table of Contents

Foreword

Purpose and Scope

This manual contains the operation and maintenance instructions for the American Magnetics, Inc. Model 185/186 Liquid Level Instrument. The manual outlines the instructions for instrument use in various system designs. Since it is impossible to cover all possible system/sensor designs, the most common configuration is discussed and the user is encouraged to contact an authorized AMI Technical Support Representative for information regarding specific configurations not explicitly covered in this manual.

Contents of This Manual

Introduction introduces the reader to the functions and characteristics of the instrument. It provides the primary illustrations of the front and rear panel layouts as well as documenting the performance specifications.

Installation describes how the instrument is unpacked and installed in conjunction with ancillary equipment in a typical cryogenic system.

Operation describes how the instrument is used to measure and control liquid level. *All* instrument controls are documented.

Remote Interface Reference documents all remote commands and queries available through the serial and IEEE-488 interfaces. A quick-reference summary of commands is provided as well as a detailed description of each.

Service provides guidelines to assist Qualified Service Personnel in troubleshooting possible system and instrument malfunctions. Information for contacting AMI Technical Support personnel is also provided.

The ***Appendix*** documents the rear panel connectors.

Applicable Hardware

The Model 185/186 has been designed to operate with an AMI Liquid Level Sensor. Operation with other equipment is not recommended and may void the warranty.

General Precautions

Cryogen Safety

Personnel handling cryogenic liquids should be thoroughly instructed and trained as to the nature of the liquids. Training is essential to minimize accidental spilling. Due to the coldness of these materials, a cryogen spilled on many objects or surfaces may damage the surface or cause the object to shatter, often in an explosive manner.

Inert gases released into a confined or inadequately ventilated space can displace sufficient oxygen to make the local atmosphere incapable of sustaining life. Cryogenic liquefied gases are potentially extreme suffocation hazards since a small amount of liquid will vaporize and yield a very large volume of oxygen-displacing gas. Always ensure the location where the cryogen is used is well ventilated. Breathing air with insufficient oxygen content may cause unconsciousness without warning. If a space is suspect, purge the space completely with air and test before entry. If this is not possible, wear a forced-air respirator and enter only with a co-worker standing by wearing a forced-air respirator.

Cryogenic liquids, due to their extremely low temperatures, will burn the skin in a similar manner as would hot liquids. Never permit cryogenic liquids to come into contact with the skin or allow liquid nitrogen to soak clothing. Serious burns may result from careless handling. Never touch uninsulated pipes or vessels containing cryogenic liquids. Flesh will stick to extremely cold materials. Even nonmetallic materials are dangerous to touch at low temperatures. The vapors expelled during the venting process are sufficiently cold to burn flesh or freeze optic tissues. Insulated gloves should be used to prevent frost-bite when operating valves on cryogenic tanks. Be suspicious of valves on cryogenic systems; the extremes of temperature they undergo causes seals to fail frequently.

In the event a person is burned by a cryogen or material cooled to cryogenic temperatures, the following first aid treatment should be given pending the arrival and treatment of a physician or other medical care worker:

1. If any cryogenic liquid contacts the skin or eyes, immediately flush the affected area gently with tepid water (102°F – 105°F, 38.9°C – 40.5°C) and then apply cold compresses.

2. Do not apply heat. Loosen any clothing that may restrict circulation. Apply a sterile protective dressing to the affected area.

3. If the skin is blistered or there is any chance that the eyes have been affected, get the patient immediately to a physician for treatment.

Containers of cryogenic liquids are self pressurizing (as the liquid boils off, vapor pressure increases). Hoses or lines used to transfer these liquids should never be sealed at both ends (i.e. by closing valves at both ends).

When pouring cryogenic liquids from one container to another, the receiving container should be cooled gradually to prevent damage by thermal shock. The liquid should be poured slowly to avoid spattering due to rapid boil off. The receiving vessel should be vented during the transfer.

Introduction of a substance at or near room temperature into a cryogenic liquid should be done with great caution. There may be a violent gas boil off and a considerable amount of splashing as a result of this rapid boiling. There is also a chance that the material may crack or catastrophically fail due to forces caused by large differences in thermal contraction of different regions of the material. Personnel engaged in this type of activity should be instructed concerning this hazard and should always wear a full face shield and protective clothing. If severe spraying or splashing could occur, safety glasses or chemical goggles along with body length protective aprons will provide additional protection.

The properties of many materials at extremely low temperatures may be quite different from the properties that these same materials exhibit at room temperatures. Exercise extreme care when handling materials cooled to cryogenic temperatures until the properties of these materials under these conditions are known.

Metals to be used for use in cryogenic equipment application must posses sufficient physical properties at these low temperatures. Since ordinary carbon steels, and to somewhat a lesser extent, alloy steels, lose much of their ductility at low temperatures, they are considered unsatisfactory and sometimes unsafe for these applications. The austinetic Ni-Cr alloys exhibit good ductility at these low temperatures and the most widely used is 18-8 stainless steel. Copper, Monel®, brass and aluminum are also considered satisfactory materials for cryogenic service.

Safety Summary

Cryogenic storage systems are complex systems with the potential to seriously injure personnel or equipment if not operated according to procedures. Proper use of safety mechanisms (pressure relief valves, rupture disks, etc.) included in the cryostat and top plate assembly are necessary.

Recommended Safety Equipment

- First Aid kit
- Fire extinguisher rated for class C fires
- Leather gloves
- Face shield
- Signs to indicate that there are potentially dangerous cryogens in use in the area.

Safety/Manual Legend

 Instruction manual symbol: the product is marked with this symbol when it is necessary for you to refer to the instruction manual in order to protect against damage to the product or personal injury.

 Hazardous voltage symbol.

~ Alternating Current (Refer to IEC 417, No. 5032).

O Off (Supply) (Refer to IEC 417, No. 5008).

| On (Supply) (Refer to IEC 417, No. 5007).

Warning

The Warning sign denotes a hazard. It calls attention to a procedure or practice, which if not correctly adhered to, could result in personal injury. Do not proceed beyond a Warning sign until the indicated conditions are fully understood and met.

Caution

The Caution sign denotes a hazard. It calls attention to an operating procedure or practice, which if not adhered to, could cause damage or destruction of a part or all of the product. Do not proceed beyond a Caution sign until the indicated conditions are fully understood and met.

Model 186 This marking in the left margin of the manual designates a feature, procedure, or specification that is unique to the Model 186.

1 Introduction

1.1 Model 185/186 Features

The American Magnetics, Inc. (AMI) Model 186 Liquid Level Controller system is an advanced, microprocessor-based solution designed to provide accurate and reliable level monitoring and control of virtually any cryogenic liquid.

1.1.1 Capacitance-based level sensing

The system consists of a Model 185/186 Liquid Level Instrument, sensor, connecting cables, and an optional solenoid-operated fill valve. The instrument sensing element is typically a 3/8 inch (9.5 mm) OD cylindrical capacitor constructed of stainless steel which allows a cryogenic fluid to become the dielectric between the concentric plates. The instrument measures the sensor capacitance which is directly related to the percentage of the sensor immersed in the cryogenic liquid. The sensors are normally constructed in overall lengths of up to 20 feet (6.1 m). The maximum active length is typically 7 inches less than the overall sensor length.

1.1.2 HI/LO level alarms

The Model 185/186 provides two alarm setpoints for both HI and LO level indication. The HI and LO level alarms activate front panel LEDs, an audible alarm, and two independent sets of relay contacts accessible from the rear panel. All setpoints are continuously adjustable from the front panel.

1.1.3 Level control

Model 186

The Model 186 adds two additional setpoints which are used to specify a control band for the liquid level. The Model 186 automatically energizes and de-energizes a rear panel controller output receptacle which is typically used to operate a solenoid valve. The controller output receptacle state can be manually overridden from the front panel. A fill timeout feature is also provided which can be used to terminate the fill function after a user-specified period of time.

1.1.4 Convenient display

The instrument is equipped with a 4-digit LED display which provides liquid level indication in inches, centimeters, or percent as selected by a front panel switch. A front panel switch allows the user to adjust the instrument length quickly and easily for a specific active sensor length. The sensor active length can be entered in either inches or centimeters.

The length adjustment only affects the scaling of the level display and does not change the actual calibration of the instrument.

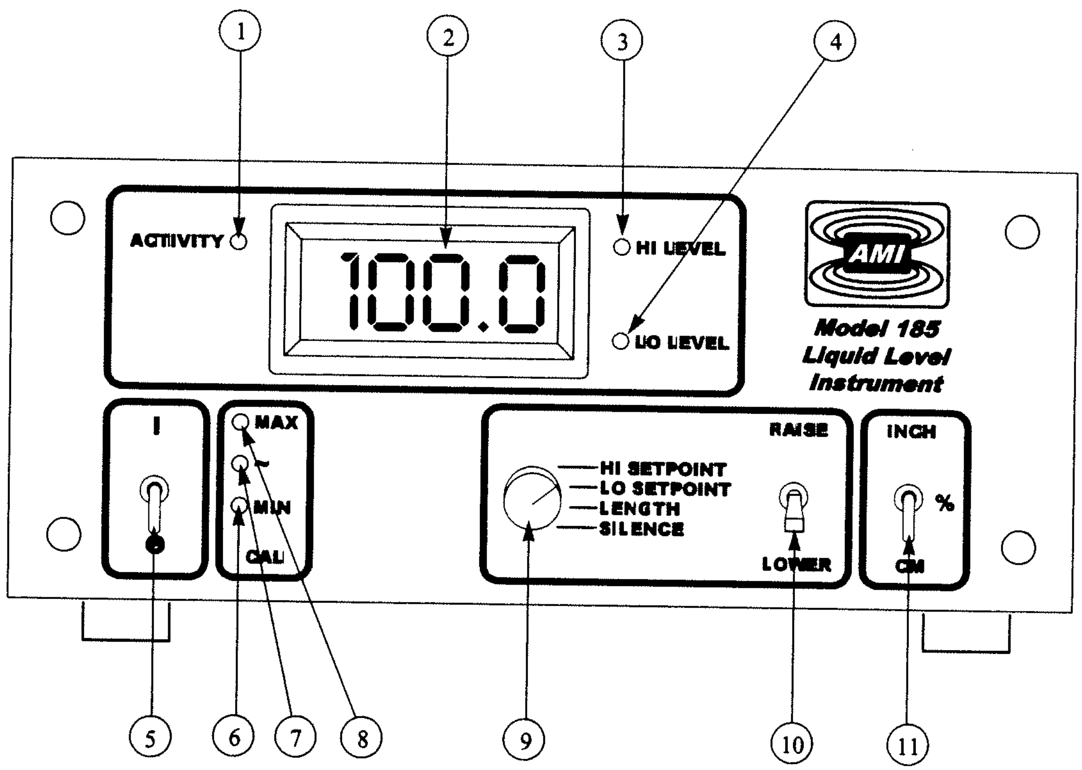
1.1.5 Microprocessor-based electronics

Microprocessor-based electronics provide 0.1% readout accuracy. Nonvolatile memory maintains instrument calibration without battery backup. Watchdog timer circuitry and low line voltage (brownout) detector prevent microprocessor lockup and provide fail-safe operation.

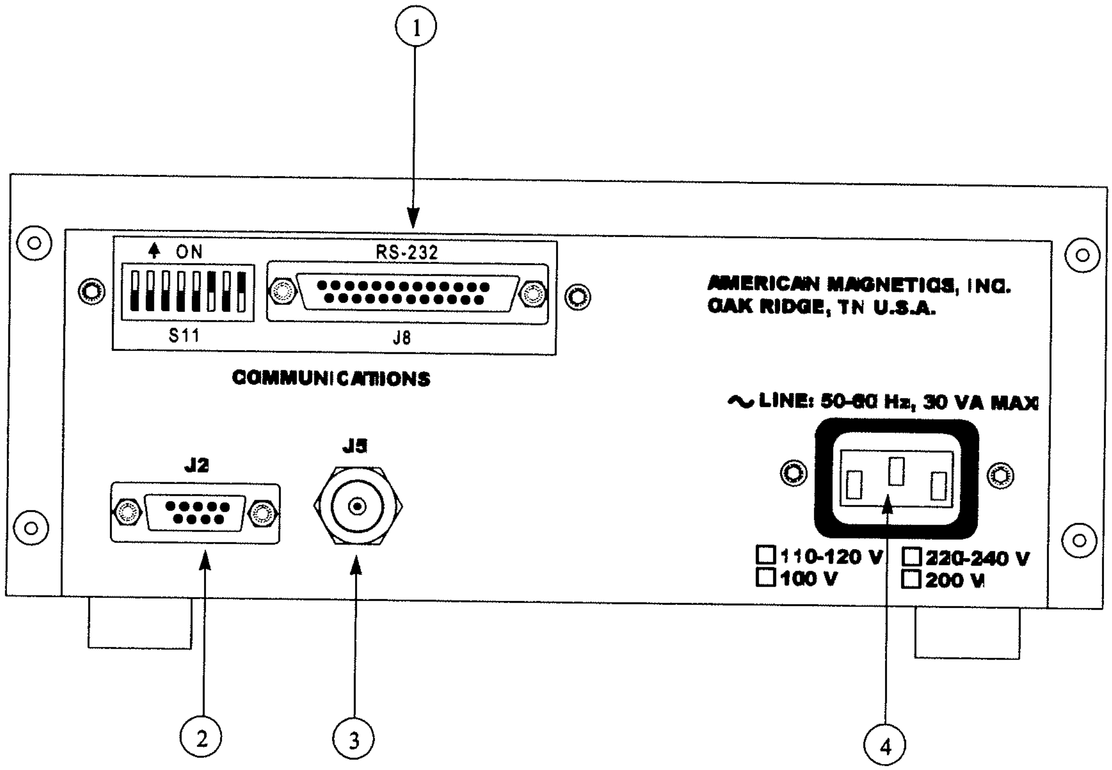
1.1.6 Remote computer monitoring or controlled operation

The Model 185/186 can be optionally equipped with a 0-10 volt recorder output. A 4-20 mA current loop option is available in lieu of the recorder output. Available computer interface options include RS-232/422 Serial Port/Data Logger or IEEE-488.

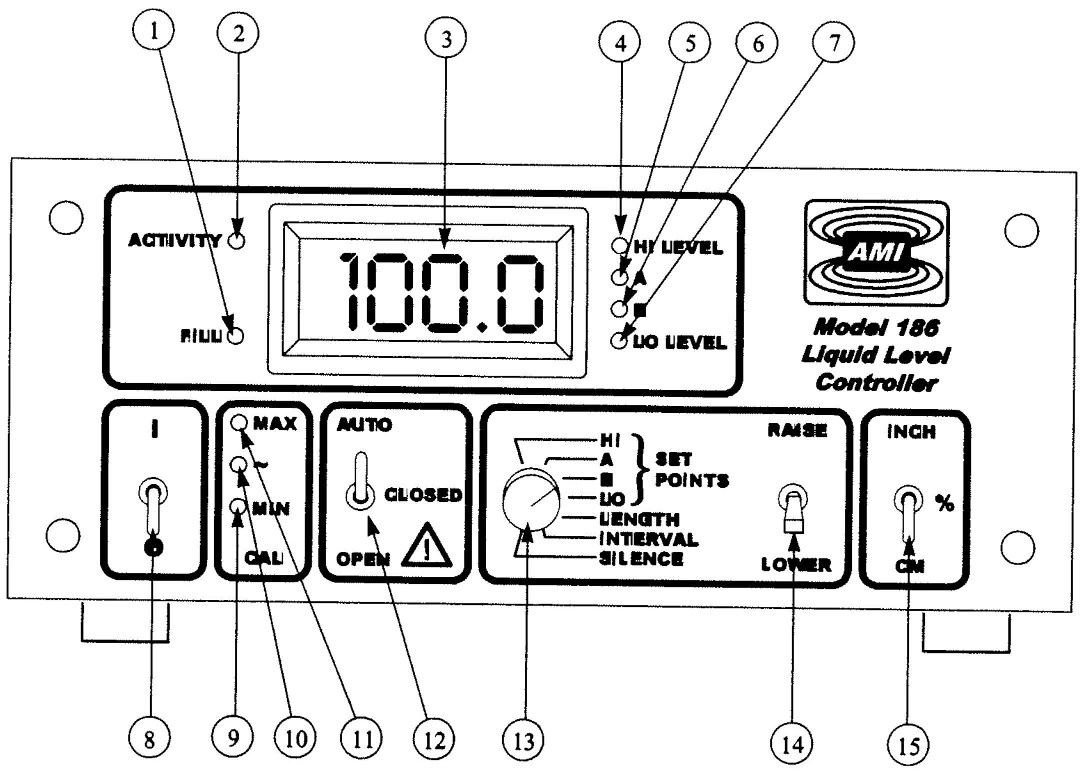
The Model 185/186 may be optionally configured for a maximum of one analog output option and one computer interface option.



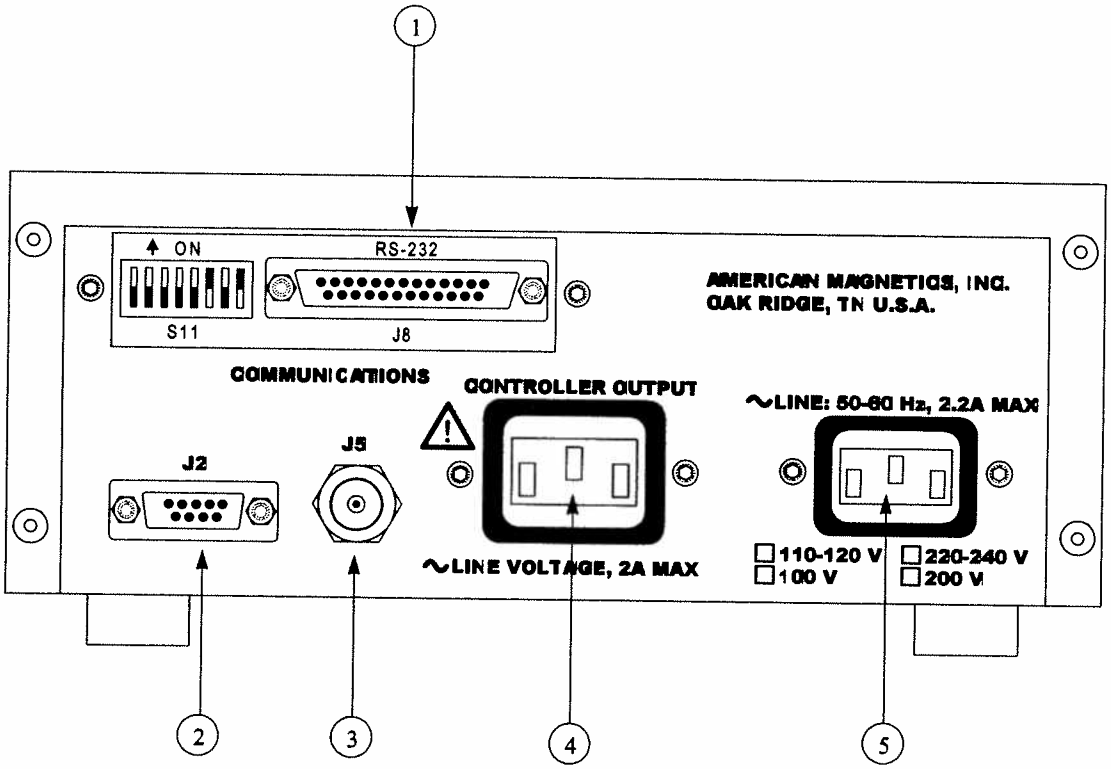
1	Activity LED	**6**	MIN calibration push-button
2	LED display	**7**	Approximate calibration push-button
3	HI level LED	**8**	MAX calibration push-button
4	LO level LED	**9**	Control mode rotary switch
5	Power toggle switch	**10**	Raise/lower toggle switch
		11	Units mode toggle switch



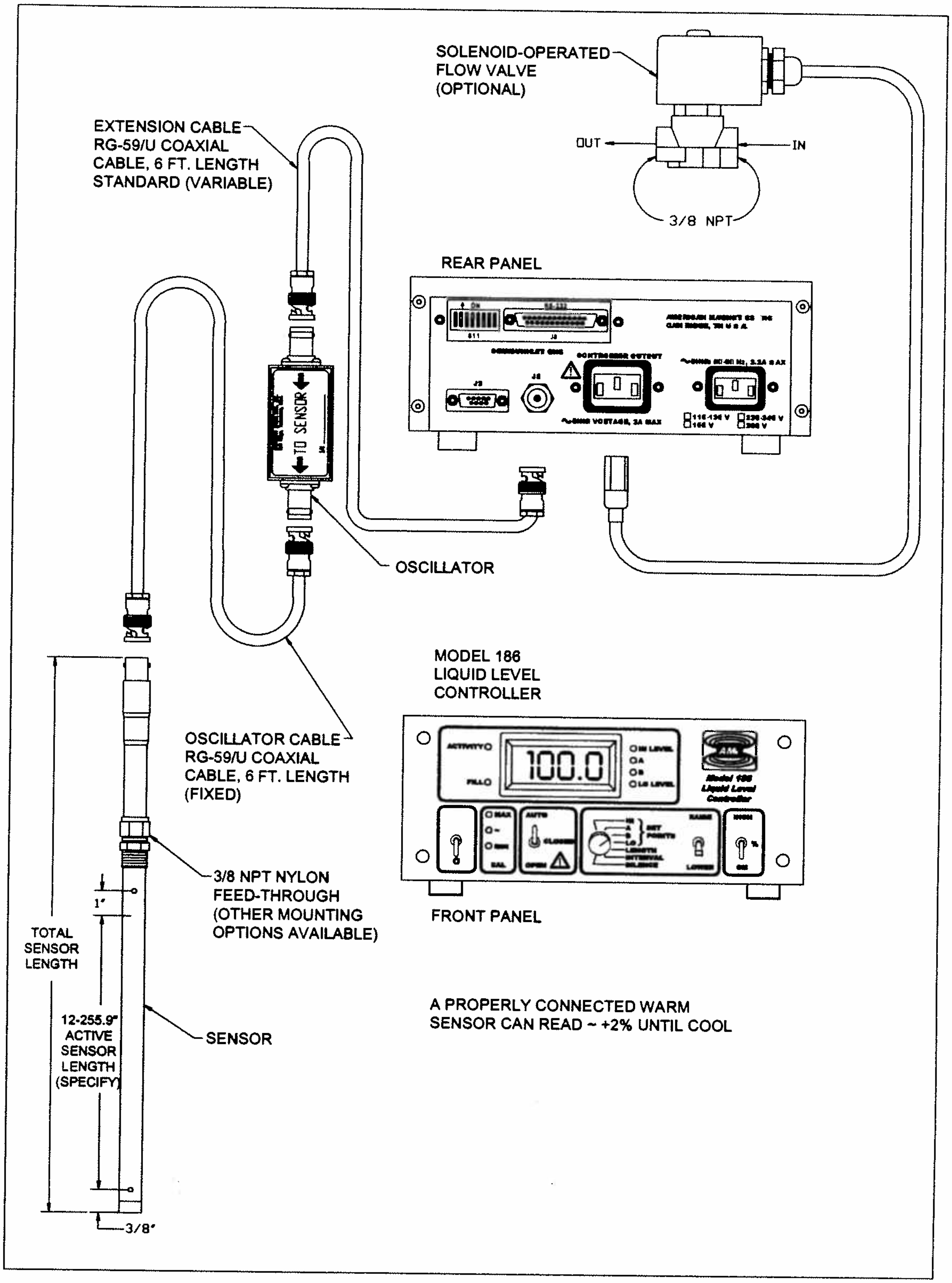
1	Optional RS-232/422 or IEEE-488 communications port (RS-232 shown)	**3**	RG-59/U coaxial connector to oscillator unit via the extension cable
2	Auxiliary DB-9 connector (see *Appendix* for pinout)	**4**	Input power connector



1	Fill indication LED	**9**	MIN calibration push-button
2	Activity LED	**10**	Approximate calibration push-button
3	LED display	**11**	MAX calibration push-button
4	HI level LED	**12**	Fill toggle switch
5	A level LED (control band upper limit)	**13**	Control mode rotary switch
6	B level LED (control band lower limit)	**14**	Raise/lower toggle switch
7	LO level LED	**15**	Units mode toggle switch
8	Power toggle switch		



1	Optional RS-232/422 or IEEE-488 communications port (RS-232 shown)	**4**	Controller output receptacle
2	Auxiliary DB-9 connector (see *Appendix* for pinout)	**5**	Input power connector
3	RG-59/U coaxial connector to oscillator unit via the extension cable		



Model 186 instrument, control valve, and sensor system diagram.

1.6 Model 185/186 Specifications @ 25 °C

Level Measurements[a]

Resolution:	0.1%, 0.1 cm, or 0.1 in
Linearity:	± 0.1%
Maximum Length Readout:	650.0 cm (255.9 in)

Operating Parameters

	HI and LO Alarms:	0% to 100% adjustable
	HI/LO Alarm Relay Contact Ratings:	10 VA, 30 VAC or 60 VDC, 0.5 A (normally open, closed on alarm)
Model 186	A and B Control Setpoints:	0% to 100% adjustable
Model 186	Controller Output:	AC line voltage @ 2A max current
Model 186	Fill Timer:	0.1 to 600.0 minutes

0-10 Volt Analog Output

Integral Non-linearity:	± 0.012%
Resolution:	16 bits
Total Error:	± 1.1% for 0-10 V output
Voltage Drift (0-10 V):	100 ppm / °C
Maximum Load:	4 mA (2.5 kΩ @ 10 V output)

4-20 mA Analog Output @ 24 V

V_{ext} Supply Range:	13-32 VDC (see *Appendix* for diagram)
Voltage Compliance:	$V_{ext} - 3.5$
Integral Non-linearity:	± 0.012%
Resolution:	16 bits
Total Error:	± 0.25% for 4-20 mA output
Current Drift (4-20 mA):	75 ppm / °C
PSRR:	10 µA / V

Power Requirements

Primary[b]:	110-120 or 208-240 VAC ±10% 50 - 60 Hz *For Japan or S. Korea*: 100 or 200 VAC ±10%
Maximum Current:	30 VA for Model 185 2.2 A for Model 186

Physical

Dimensions (Standard):	97 mm H x 213 mm W x 282 mm D (3.8" H x 8.4" W x 11.1" D)
Weight (Standard):	1.6 kg (3.6 lbs.)
Dimensions (Rack Mount):	89 mm H x 483 mm W x 282 mm D (3.5" H x 19" W x 11.1" D)
Weight (Rack Mount):	2.0 kg (4.3 lbs.)

Environmental

Ambient Temperature:	Operating: 0 °C to 50 °C (32 °F to 122 °F) Nonoperating: –20 °C to 60 °C (–4 °F to 140 °F)
Relative Humidity:	0 to 95%; non-condensing

a. Under extreme radiated electromagnetic field conditions (3V/m at 450 MHz to 610 MHz), the accuracy may be degraded by an additional ±0.7%.
b. Units configured for Japan or South Korea cannot be configured for operation at other voltages without an internal transformer change, and vice-versa.

2 Installation

Warning

Before energizing the instrument, the earth ground of the power receptacle must be verified to be at earth potential and able to carry the rated current of the power circuit. Using extension cords should be avoided; however, if one must be used, ensure the ground conductor is intact and capable of carrying the rated current.

In the event that the ground path of the instrument becomes less than sufficient to carry the rated current of the power circuit, the instrument should be disconnected from power, labeled as unsafe, and removed from place of operation.

Do not operate this instrument in the presence of flammable gases. Doing so could result in a life-threatening explosion.

Do not modify this instrument in any way. If component replacement is required, return the instrument to AMI facilities as described in the Service section of this manual.

If the instrument is used in a manner not specified by AMI, the protection provided by the equipment may be impaired.

2.1 Unpacking the Instrument

Carefully remove the instrument, sensor, oscillator and interconnecting coaxial cables from the shipping carton and remove all packaging material. A rack mounting kit is supplied if the instrument was purchased with the rack mount option.

Note

If there is any shipping damage, save all packing material and contact the shipping representative to file a damage claim. Do not return the instrument to AMI unless prior authorization has been received.

If the chassis is a table top model, place the instrument on a flat, secure surface.

2.2 Rack Mounting the Instrument

If the instrument has a rack mount chassis, follow the following procedure:

a. Attach the rack mount adapter pieces to the instrument by first removing the four screws on the side of the instrument that attach the cover to the chassis. Attach the rack mount adapter pieces to the sides of the instrument by reinstalling the screws.

b. Install the instrument in a 19" rack by securing the front panel to the rail in each of the four corners with mounting hardware supplied by the cabinet manufacturer.

Warning

Do not remove the cabinet feet and then reinsert the original screws. Doing so could present a severe life-threatening electrical hazard. If removal of the cabinet feet is desired, replace the original screws with screws not to exceed 1/4" in length. Screws longer than 1/4" will contact and damage the printed circuit board inside the unit.

2.3 Installing the Sensor in the Cryo-vessel

Exercise care when installing the sensor since dents, crimps, bends or other physical distortions in the thin wall capacitor will change electrical characteristics possibly causing calibration errors and/or disruption of proper instrument operation. Before installing the sensor, the user may want to review the *Calibration* and *Operation* sections to determine what, if any, calibration procedures may be necessary.

Note

The coaxial interconnecting cables and the oscillator are temperature sensitive and should be mounted in such a manner as to avoid large temperature changes such as those encountered in the path of dewar vents.

2.4 Connecting the Oscillator Cable to the AMI Sensor

Connect the oscillator to the sensor using a supplied 6 foot RG-59/U coaxial cable. Ensure the oscillator is connected in the correct orientation (see page 7 for a system diagram). The cable length between the oscillator and the sensor should not exceed 6 feet unless longer lengths were discussed with an Authorized AMI Technical Representative.

Caution

Moisture or contaminants in any of the BNC coaxial connectors can short out the sensor and cause a false 'full' level indication or other erroneous readings. A pack of non-conductive electrical connection lubricant (ECL or "Dielectric Tune-up Grease") has been included with the liquid level sensor packaging to reduce the possibility of this occurring. If desired, apply a small amount of ECL to any of the BNC connectors that may be exposed to moisture. Mate the doped connectors then remove any excess ECL from the outside of the connector. Added protection can be achieved by covering the doped connections with a short section of heat-shrink tubing.

Note: MSDS sheets for the ECL are available upon request.

2.5 Connecting the Instrument to the Oscillator

Caution

Operation of the AMI Model 185/186 Liquid Level Instrument with a device other than an AMI Liquid Level Sensor may void the instrument warranty.

Using the J5 coaxial connector, connect the instrument to the oscillator using a RG-59/U coaxial cable. The length of the extension cable can be varied to suit the specific application. AMI has confirmed proper operation for up to 500 feet of coaxial cabling between the instrument and oscillator.

2.6 Installing an Optional Solenoid-operated Fill Valve

Model 186

Install a solenoid-operated fill valve by connecting the valve power cable to the AC controller output receptacle on the rear panel of the instrument. The standard AMI supplied valve has a 9/32 inch orifice and the input and output are tapped for 3/8 NPT. Operation of the controller output receptacle in AUTO mode should be avoided until the instrument setpoints have been specified. See the *Operation* section for details on specifying the setpoints and selecting the operational mode for the controller output receptacle.

Caution

When using a solenoid-operated control valve with the Model 186, ensure the valve is configured for the operating voltage of the Model 186. Failure to do so will result in faulty operation and may also result in valve damage.

Warning

Before touching any of the controller output receptacle terminals or touching the wiring connected to these terminals, remove power to the instrument by unplugging it or turning the power switch to the off position.

The controller output receptacle conducts hazardous AC line voltage potentials. It is for use with equipment which has no live parts which are accessible. Conductors connected to its terminals must be insulated from user contact by reinforced or double insulation capable of withstanding 4250 V (impulse) for a 240 VAC Category II installation, or 2550 V (impulse) for a 120 VAC Category II installation.

This instrument is designed for operation from a single-phase power source for maximum safety. The controller output receptacle circuitry only switches the "line" ("hot") connection to the AC mains. If two-phase power is applied, any equipment connected to the controller output receptacle conducts hazardous AC voltage even when the controller output receptacle is not energized.

2.7 Connecting the Instrument to Power

Warning

The Model 185/186 operates on 50-60 Hz power and may be configured for 110-120 or 208-240 VAC ±10% (100 or 200 VAC ±10% for Japan and South Korea). The power requirements for each instrument is marked on the calibration sticker on the bottom of the instrument. Be sure your instrument is configured for your power source prior to plugging in the line cord. Do not fail to connect the input ground terminal securely to an external earth ground.

Ensure the front panel switch is in the OFF position. Verify that the instrument is configured for the proper operating voltage by referring to the calibration sticker affixed to the bottom of the instrument. If the operating voltage is correct, plug the line cord into the appropriate power receptacle.

Warning

Do not install the instrument in a manner that prevents removal of the line cord from the rear panel of the instrument.

3 Calibration

Model 185/186 instruments are calibrated at the factory for a specific length sensor for use in a specific liquid. The calibration length and calibration liquid are listed on the calibration sticker on the bottom of the instrument. If the factory calibration method utilized was approximate, the calibration length will be noted as an approximate value.

3.1 Relationship between Calibration and Sensor Length

The capacitance-based method of measuring the liquid level operates by measuring the frequency of an oscillator, which is contained in the oscillator/transmitter unit. As the liquid level varies, the value of the capacitance varies proportionally. Since the dielectric properties of liquids vary and the component tolerances for the sensor and oscillator introduce variations, a calibration is required to assure maximum accuracy for a specific sensor immersed in the target liquid. The calibration MIN and MAX settings correspond to the maximum and minimum oscillation frequencies, respectively, for a given sensor and target liquid configuration.

The LENGTH setting of the instrument is only provided as a means of scaling the 0% (MIN) to 100% (MAX) range of the measurement to meaningful units of length. During the calibration it is important to accurately measure the distance between the physical locations on the sensor corresponding to the MAX and MIN calibration points. The measured value for the length will be used in configuring the instrument for operation.

3.2 Variations in the Dielectric with Changing Density

For cryogenic liquids, the dielectric of the liquid will change with a change in density. The amount of change is dependent on the properties of the specific liquid. Figure 3-1 illustrates the variations in dielectric for nitrogen vs. pressure under *saturated* conditions.[1] Since the instrument uses a capacitance-based method for determining liquid level, such a change in the dielectric of the liquid will result in a shift in the level reading of the instrument. The calibration procedures described herein are most accurate when applied in situations where the operating conditions of the cryo-vessel are relatively constant, i.e. the operating pressure and temperature of the cryo-vessel are relatively constant.

1. Data obtained from NIST Standard Reference Database 12.

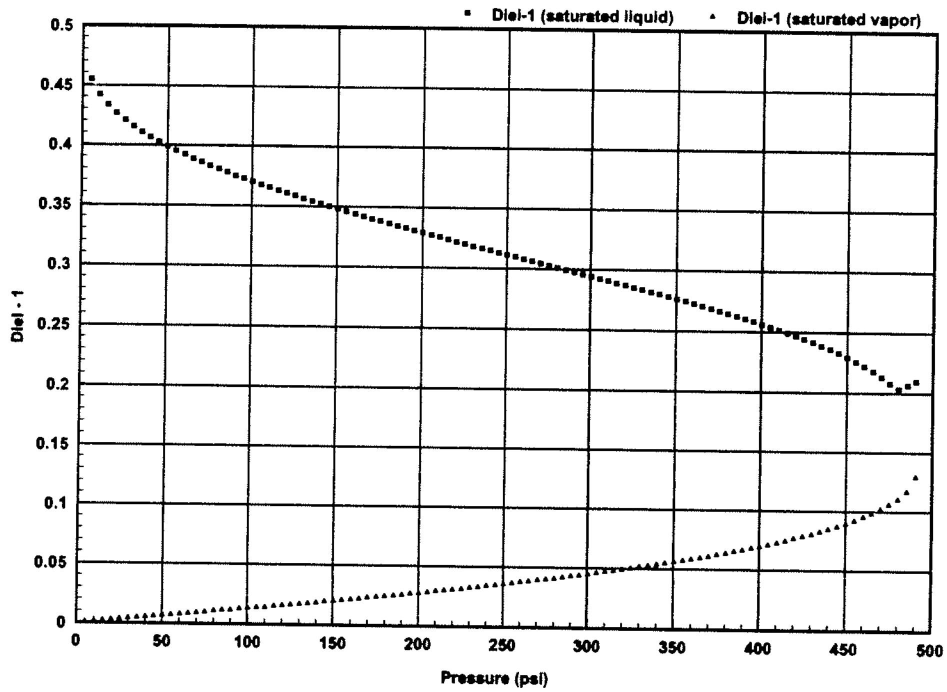


Figure 3-1. Dielectric vs. pressure for nitrogen under saturated conditions.

To minimize the effects of shifts in the dielectric of the target liquid, perform a closed dewar calibration (see page 21) at the expected operating condition of the cryo-vessel. If this is not feasible, then calibrate the sensor at atmospheric pressure and use the approximate calibration method to compensate for the shift of the dielectric when the cryogenic liquid is under pressure. For this type of approximate calibration, the *reference liquid* will be the *target liquid* at atmospheric pressure — see page 25 for a detailed discussion of the approximate calibration method. If any questions exist in regard to calibration issues, contact AMI for assistance in determining the optimal calibration strategy.

If higher accuracy is required, please contact an Authorized AMI Technical Representative with your requirements. AMI can supply a self-compensating, capacitance-based, liquid level sensing system (e.g. the Model 187) for applications in cryo-vessels with a wide range of operating conditions, or for applications where increased accuracy over a range of operating conditions is desired. The self-compensating design also possesses the advantage of factory calibration for all cryogens, i.e. no calibration is required of the user for most applications.

Note

All references to "dielectric constant" herein refer to the unitless relative dielectric to ε_0 (ε_0 is the dielectric constant of a vacuum).

3.3 Calibration Methods for Model 185/186 Instruments

The most straightforward calibration method is the *Open Dewar Calibration* which requires the customer to have access to a filled dewar where the full active length of the sensor can be dipped. The *Closed Dewar Calibration* method can be performed in situations where it is not feasible for the customer to dip the sensor into an open dewar, such as situations where the target liquid is under pressure. The closed dewar calibration is more complex and may require initial preparations to insure success.

Occasionally customers ask AMI to calibrate an instrument and sensor for a liquid which is not available at AMI for calibration purposes and/or for a sensor which is too long to be calibrated at our facilities.

For the case of the target liquid being unavailable, AMI uses liquid nitrogen as the reference liquid and an *Approximate Calibration* is performed using mathematical manipulation of the ratio of the dielectric constants between liquid nitrogen and the desired liquid. This procedure is outlined in the *Approximate Calibration* section beginning on page 25. The technique is intended to provide the instrument with an approximate calibration so that it can be used immediately by the customer. However, the customer is still expected to perform a more accurate calibration where feasible, such as the open dewar or closed dewar calibration, with the target liquid.

For the case where a sensor is too long to be calibrated in AMI facilities, AMI will perform a partial length open dewar calibration in liquid nitrogen, and then calculate the MAX calibration point. A dielectric ratio may also be subsequently utilized to adjust for a target liquid other than liquid nitrogen. The customer is expected to perform a more accurate open dewar or closed dewar calibration if feasible.

As a quick guide for selection of the best calibration method available, a calibration selection diagram is presented below. If the instrument and sensor are purchased as a unit from AMI, then the factory calibration will be adequate in most cases. However, for the exceptions noted in the previous paragraphs (which are *approximate* calibrations), the customer should perform a more accurate open dewar or closed dewar calibration. A customer performed calibration is also required for sensors that are purchased as a separate item from the instrument, since the instrument and sensor were not both available for calibration at AMI facilities.

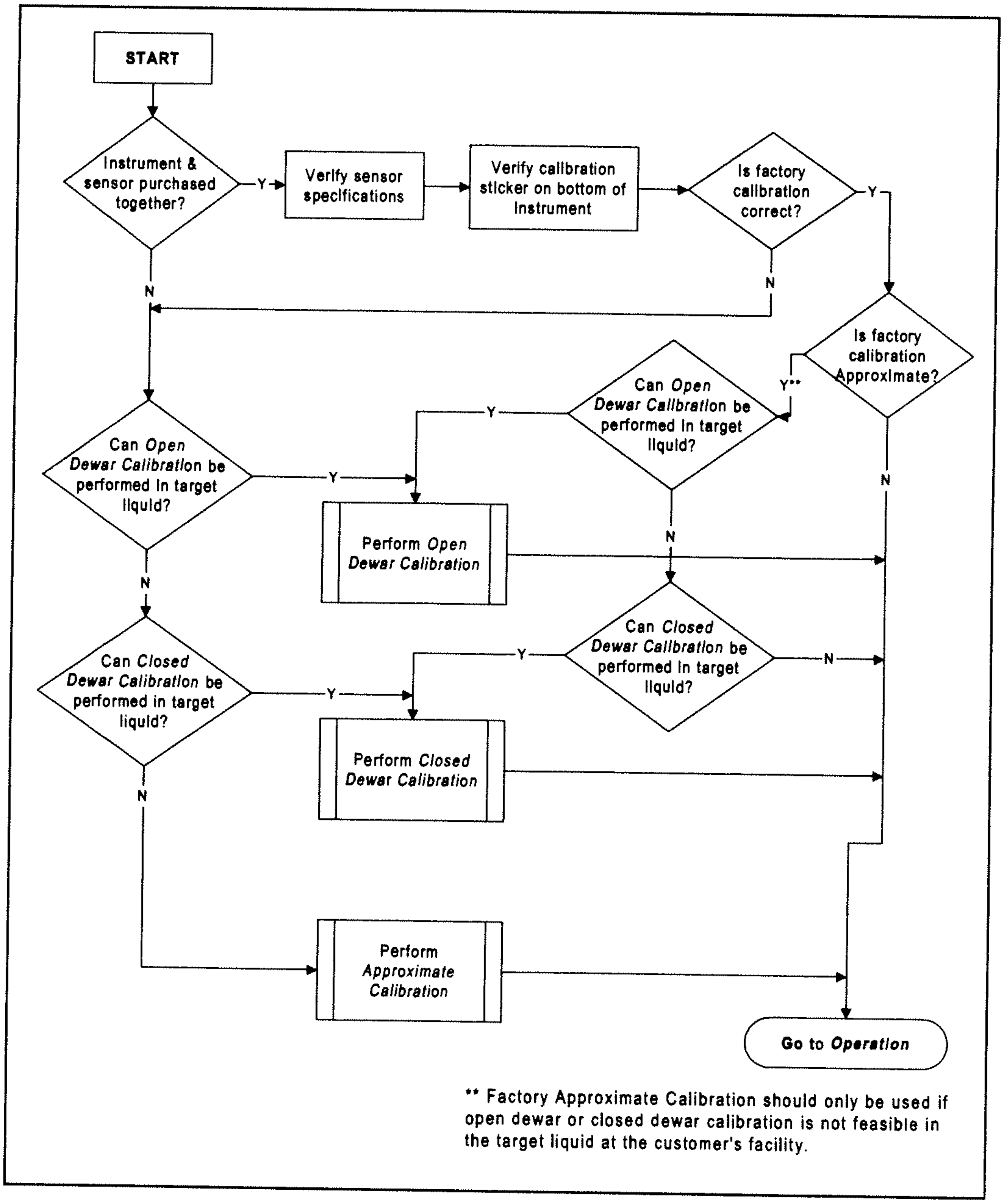


Figure 3-2. Calibration method selection diagram.

3.3.1 Open dewar calibration

The instrument should be energized with the sensor connected to the instrument via the oscillator (see the system diagram on page 7).

1. Slowly insert the sensor into the liquid until the level rests approximately one inch below the top sensor hole and then press the MAX push-button through the small hole provided on the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released. The location of the liquid level on the sensor when the MAX button is pressed becomes the 100% level. The 100% level should always be lower than the upper hole to ensure the instrument will always reach 100% in the event the overall sensor capacitance changes slightly due to component drift, pressure variations, fluid impurities, etc.

2. Slowly withdraw the sensor out of the liquid to be measured until the level is approximately even with the bottom hole in the sensor and then press the MIN push-button through the small hole provided in the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released. The location of the liquid level on the sensor when the MIN button is pressed becomes the 0% level. This completes the calibration procedure.

   Note

   Having a small amount of liquid in contact with the sensor at the MIN calibration level helps stabilize the sensor capacitance for 0% level indication.

3. Permanently install the sensor in the vessel and proceed to the *Operation* section for directions for configuring the instrument.

3.3.2 Closed dewar calibration

A calibration can be performed in a closed dewar system by monitoring the liquid level while transferring the target liquid to an initially empty (or near empty) dewar at a constant rate. In order to insure success with the closed dewar technique, it is necessary to prepare the instrument by presetting the calibration MIN and MAX points outside the estimated level range. If the instrument is not prepared in this manner before the calibration procedure, it is possible to reach the MAX calibration point of the instrument before the target vessel is at the desired maximum level point. If minimum and maximum liquid level indication is available via some other means (e.g. flow calculation, visual determination, point sensors, etc.), then the presetting of the instrument is not necessary.

3.3.2.1 Presetting the MAX/MIN calibration points

The following procedure should be performed before installation of the sensor in the target cryo-vessel.

1. Connect the extension and oscillator cables to the J5 coaxial connector on the rear panel of the instrument (see page 7 for a system diagram). *Do not connect the sensor.* Energize the instrument. Press the MIN push-button through the small hole provided on the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released.

2. Connect the sensor to the oscillator cable (which is still connected to the instrument via the extension cable). Press the MAX push-button through the small hole provided on the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released.

3. Calculate the factor C_{adj} using the following equation:

$$C_{adj} = 120\left[1 + \frac{2.1(L_{active})}{5.2(L_{total})}\right]\left[\frac{e-1}{0.454}\right]$$

   where L_{total} is the total sensor length in inches, L_{active} is the active sensor length in inches, and *e* is the dielectric constant of the target liquid.

4. Enter C_{adj} into the instrument by placing the front panel control mode rotary switch in the SILENCE position. By using the RAISE/LOWER toggle switch and holding it in the up or down position, adjust the displayed value up or down. The display will move slowly at first and then faster. Once near the desired value, simply release the switch momentarily and then resume changing the factor at the slower speed. Once the desired number has been reached, release the toggle switch.

5. Once the value for C_{adj} has been entered, momentarily press the CAL push-button labeled as "~" (the tilde character) through the small hole provided in the instrument front panel. When the value has been accepted, the display will show "ddd.d" and the button can then be released.

6. With the sensor connected, again press the MIN push-button through the small hole provided on the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released. The presetting procedure is complete. Proceed to the remainder of the closed dewar calibration procedure as presented below.

3.3.2.2 Completing the closed dewar calibration procedure

1. Install the sensor in the dewar and energize the instrument with the sensor connected to the instrument via the oscillator and extension cables (see the system diagram on page 7).

2. Set the LENGTH to the active length of the sensor. After setting the LENGTH, set the units mode toggle switch to the % setting. For details on setting the LENGTH and units mode, refer to the *Operation* section of this manual.

3. Connect a strip chart recorder to the recorder output terminals on the rear panel of the instrument. If the recorder output is not available, the 4-20 mA current loop output may be used if installed, or an installed communications option can be used to query the instrument for the liquid level at regular time intervals during the calibration procedure. If no remote monitoring or communication option is installed, the level display must be manually plotted vs. time during the procedure.

4. Commence filling the dewar. While the sensor is cooling down, there may be a slow drift in the displayed liquid level. However, when the liquid actually touches the bottom of the sensor, contact with the liquid surface may become apparent by virtue of more random and frequent fluctuations in the displayed liquid level. The liquid level trace will also start to show an increasing profile with positive slope.

   Once the indications of the contact between the sensor and liquid become readily apparent, press the MIN push-button through the small hole provided in the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released. This point is the 0% level of the sensor.

   Note

   If the sensor is installed in the dewar with some small amount of liquid already in contact with the sensor, then the final MIN calibration point can be set before filling begins but after any thermally induced fluctuations in the observed output have diminished. However, note that the measured span of the liquid level is reduced by the initial level of liquid in contact with the sensor.

5. Continue the transfer while observing the liquid level trace on the strip chart recorder or computer display, whose slope is proportional to the transfer rate. The slope of the liquid level trace

should decrease significantly when the liquid reaches the hole in the top of the sensor.

When the break in the slope of the level trace occurs (i.e. the slope of the level trace becomes 0 or horizontal), push the MAX push-button through the small hole provided in the instrument front panel. When the calibration data has been accepted, the display will show "bbb.b" and the push-button can then be released. The level on the sensor when the MAX button is pressed becomes the 100% level.

Note

If the instrument displayed a 100% reading before a break is observed in the slope of the level trace, then the MAX calibration point set prior to the current procedure has interfered. If this occurs, the customer has two options: 1) stop the procedure, repeatedly enter a value of 120 *for* C_{adj} *(see steps 4 and 5 of the presetting procedure) until the current liquid level display falls below 100%, and then continue the procedure; or 2) continue the liquid transfer until the liquid level is determined to be 100% by means other than feedback from the instrument and then pressing the MAX calibration push-button.*

6. To achieve a standard calibration of the sensor with the active region located from the lower hole to one inch below the upper hole, use the level data from the instrument to recalibrate the MAX point when the percent level corresponds to one inch below the upper hole. Use the following equation to determine the percent level at which to reset the MAX calibration point:

$$MAX_{percent} = 100 - 100\left[\frac{1}{L_{active}}\right]$$

where L_{active} is the active length of the sensor in inches. This technique can be used assuming the sensor was built as a standard sensor. If the sensor was made in a custom configuration, refer to the sensor documentation and/or drawing or contact AMI.

Example: 20" active length sensor:

When the sensor is calibrated by the closed dewar procedure, the actual length of calibration will be 21" (distance between the bottom and top holes in the sensor). When the liquid is 1" below the upper hole, the display will show 95.2% [e.g. 100% – (1"/21" x 100%)]. When the liquid level reaches this point during usage, push the MAX calibrate button. The instrument and sensor are now calibrated with a standard active region of 20". The LENGTH setting of the instrument should also be configured for 20".

7. Proceed to the *Operation* section for directions for configuring the instrument.

3.3.3 Approximate calibration

This procedure is the least accurate form of calibration and should be used only when the aforementioned calibration procedures are not viable. The approximate calibration method can be used in cases where the sensor cannot be dipped into the target liquid, the full active length of the sensor cannot be dipped into an open dewar, or both. Approximate calibration may also be useful for situations where the sensor cannot be dipped into the target liquid under the expected operating pressure.

If the target liquid is not available for dipping, a substitute *non-conducting* reference liquid can be used. If the full length of the sensor cannot be dipped, then a partial length dip can be performed. If both situations are encountered, then a partial length dip can be performed in a substitute reference liquid.

1. First, cool the sensor as much as possible by dipping the sensor as far as possible in the available reference liquid.

2. Slowly withdraw the sensor out of the reference liquid until the level is approximately even with the bottom hole in the sensor and then press the MIN push-button through the small hole provided in the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released. The location of the liquid level on the sensor when the MIN button is pressed becomes the 0% level.

   Note

   Having a small amount of liquid in contact with the sensor at the MIN calibration level helps stabilize the sensor capacitance for 0% level indication.

3. Reinsert the sensor in the reference liquid as far as possible, but not exceeding 1" below the top hole. Note the physical location of the liquid level on the sensor at the maximum insertion depth. While the sensor is submerged at the maximum depth, press the MAX push-button through the small hole provided in the instrument front panel. When the calibration point has been accepted, the display will show "bbb.b" and the push-button can then be released.

4. Measure the distance between the bottom hole of the sensor and the location of the liquid level noted during step 3. This measured length is L_{dipped}.

5. The dielectric constant for the reference liquid, e_1, and the target liquid, e_2, must be known to complete the approximate calibration. These values must be placed in the equation:

$$\text{Approximate Calibration Factor} = \left[\frac{e_2 - 1}{e_1 - 1} \times 100\right]\frac{L_{active}}{L_{dipped}}$$

   where L_{dipped} is the length of the sensor dipped in the reference liquid and L_{active} is the active sensor length.

   Note

   If the target liquid is available for dipping (i.e. the reference liquid and target liquid are the same), then the dielectric ratio, $(e_2-1)/(e_1-1)$, *becomes* 1. *If the full active length of the sensor can be dipped, then the length ratio,* L_{active} / L_{dipped}, *becomes* 1.

   Note that e_1 = 1.454 for liquid nitrogen at –203°C at atmospheric pressure. Dielectric constants for several liquids are provided in the *Appendix.* The dielectric constant varies with temperature and pressure, therefore for best accuracy use the dielectric constant for the target liquid at the temperature and pressure maintained in the containing vessel.

6. Once the approximate calibration factor is calculated, it can be entered into the instrument by placing the front panel control mode rotary switch in the SILENCE position. By using the RAISE/ LOWER toggle switch and holding it in the up or down position, you can adjust the approximate calibration factor up or down. The display will move slowly at first and then faster. Once near the desired value, simply release the switch momentarily and then resume changing the factor at the slower speed. Once the desired number has been reached, release the toggle switch.

7. Once the approximate calibration factor has been entered, momentarily press the CAL push-button labeled as "~" (the tilde character) through the small hole provided in the instrument front panel. When the calibration factor has been accepted, the display will show "ddd.d" and the button can then be released. This completes the approximate calibration procedure.

Note

The last approximate calibration factor is not retained in the instrument memory, therefore the effects of repeated approximate calibrations are cumulative.

Example: Purchased a 100" active length sensor for operation in liquid argon at atmospheric pressure, however only liquid nitrogen is available for calibration at a maximum depth of 30":

First, the sensor is dipped as far as possible into the liquid nitrogen and cooled. The MIN point is then set as outlined in step 2. The MAX point is set as outlined in step 3 while the sensor is submerged 30" in liquid nitrogen. The dielectric constant for liquid nitrogen is 1.454 and for liquid argon is 1.53. Substituting all values into the approximate calibration factor equation yields:

$$\text{Approximate Calibration Factor} = \left[\frac{1.53 - 1}{1.454 - 1} \times 100\right]\frac{100}{30} = 389.1$$

A value of 389.1 would be entered as the approximate calibration factor as outlined in steps 6 and 7. The sensor is now *approximately* calibrated for 100" active length operation in liquid argon.

8. The sensor can now be installed in the dewar containing the target liquid. The approximate calibration can be used until an open dewar or closed dewar calibration can be performed with the target liquid.

9. Proceed to the *Operation* section for directions for configuring the instrument.

4 Operation

The Model 185/186 and sensor (if applicable) were functionally tested and calibrated at the factory. The calibration sticker located on the bottom of the instrument shows the calibration length, calibration liquid, and whether an approximate calibration method was utilized at the factory. In the event that the calibration is incorrect for the application, the instrument will need to be recalibrated by the user with a specific sensor and liquid. Refer to the *Calibration* section for the specific procedures.

4.1 Normal Operations

4.1.1 Energize the instrument

After completion of the *Installation* procedures, energize the instrument by placing the power toggle switch in the POWER position. The LED display will briefly display AAAA and then indicate the liquid level, and the yellow ACTIVITY LED will begin blinking.

Note

The ACTIVITY LED provides visual indication that the microprocessor is making sensor readings. If a fault should develop which prohibits the microprocessor from operating correctly (such as a break in cabling) the LED will not blink or blink slowly, and the display will continuously show 100%.

Note

If the displayed level reading is below the LO SETPOINT level or exceeds the HI SETPOINT, an audible alarm will sound. To silence the alarm, rotate the control mode rotary switch on the front panel to the SILENCE position.

The instrument is normally calibrated at the factory for the specific sensor supplied with the unit for use in a target liquid. If the need arises for recalibration, see the *Calibration* section.

4.1.2 Configure the active length setting

After calibration, the instrument *must* be configured for the active length of the sensor in order to scale the measurement to meaningful units of length for display. For a standard calibration, the value of the active length is the sensor length between the bottom hole to 1 inch below the top hole of the sensor assembly. If the user performed a calibration, then the physical distance between the locations of the MIN and MAX calibration points on the sensor is the active length.

The instrument allows the user to display the liquid level in units of length (inches or centimeters) in addition to a percentage. The instrument was shipped with the length value set to the active sensor length if a sensor was purchased with the instrument.

To *view* the present length setting, place the units mode toggle switch in either the INCH or CM position. Place the control mode rotary switch on the front panel to the LENGTH position. Push and *release* the RAISE/LOWER toggle switch either up or down. The display will momentarily show the current length setting.

To *change* the length setting, use the RAISE/LOWER toggle switch to move the setting up or down by continuously holding it in the up or down position. The display will move slowly at first and then faster. Once near the desired value, simply release the switch momentarily and then resume changing the setpoint at the slower speed. The new active sensor length is permanently stored in memory. Check the value by momentarily placing the toggle switch in either position from the center position.

Note

The LENGTH adjustment can only be performed in the INCH or CM units modes. The LENGTH adjustment is inactive if the units are set for %.

4.1.3 Configure the HI SETPOINT and the LO SETPOINT

To adjust the HI and LO setpoints, place the control mode rotary switch in the HI SETPOINT position or the LO SETPOINT position, respectively. Use the RAISE/LOWER toggle switch to adjust the respective setpoint in the same manner as described for the LENGTH adjustment in step 2. The setpoints may be located anywhere between 0% to 100% of the active sensor length. The HI and LO setpoint adjustments are compatible with all three units modes.

a. When the measured liquid level exceeds the HI setpoint, the HI LEVEL LED on the front panel is energized and a set of relay contacts are closed on the 9-pin D connector J2 on the rear panel (see the *Appendix* for the pinout). When the level reaches or falls below the HI setpoint, the LED is extinguished and the relay contacts open.

b. When the measured liquid level falls below the LO setpoint, the LO LEVEL LED on the front panel is energized and a set of relay contacts are closed on the 9-pin D connector J2 on the rear panel (see the *Appendix* for the pinout). When the level reaches or exceeds the LO setpoint, the LED is extinguished and the contacts open.

Note

The HI and LO contacts are both closed on power-off of the instrument which is a state unique to the power-off condition.

Note

If the LENGTH is adjusted subsequent to configuring the various setpoints, the percentage of active length will be maintained for all setpoints. For example, if the LENGTH is set to 100 cm and the HI SETPOINT is set to 80 cm, then adjusting the LENGTH to 150 cm will result in the HI SETPOINT being automatically scaled to 120 cm—i.e. the setting of 80% of active length is maintained.

4.1.4 Configure the A SETPOINT and the B SETPOINT

Model 186 To adjust the A and B setpoints which specify the upper and lower limits for the liquid level control band, place the control mode rotary switch in the A SETPOINT position or the B SETPOINT position, respectively. Use the RAISE/LOWER toggle switch to adjust the respective setpoint in the same manner as described for the LENGTH adjustment in step 2. The A and B setpoint adjustments are compatible with all three units modes.

a. When the measured liquid level reaches or exceeds the A setpoint, the A LEVEL LED on the front panel is energized. When the level falls below the A setpoint, the LED is extinguished.

b. When the measured liquid level falls below the B setpoint, the B LEVEL LED on the front panel is energized. When the level reaches or exceeds the B setpoint, the LED is extinguished.

c. In addition to the LED functions, the controller output receptacle may be energized and de-energized as discussed in step 5 below.

Note

The A setpoint must always be above the B setpoint. The firmware does not allow these setpoints to be reversed. Both setpoints may be set from 0% to 100% of the LENGTH setting as long as A > B.

4.1.5 Select the operational mode of the controller output receptacle

Model 186 The operation of the CONTROLLER OUTPUT receptacle of the instrument is controlled by the fill toggle switch. Operation of the fill toggle switch is as follows:

a. **CLOSED** (or **OFF**): With the instrument power on and the fill switch in the CLOSED position, the instrument serves only as a level monitor, giving a level reading on the digital display and providing data via any analog or communication options installed. All four setpoint LEDs (and associated J2 connector relay contacts) operate normally, however, the controller output receptacle on the rear panel will *always* be de-energized.

b. **OPEN** (or **ON**): With the fill switch in the OPEN position, the rear panel CONTROLLER OUTPUT receptacle will become energized, thereby initiating flow if the solenoid-operated fill valve is properly connected. The FILL LED on the front panel will light indicating the presence of power at the controller output receptacle. **The operator is solely responsible for terminating the fill flow.**

c. **AUTO:** With the fill switch in the AUTO position, the instrument is capable of automatically initiating and terminating liquid fill via the control valve, thereby maintaining the level between the selected A and B setpoints. If the liquid level falls below the B setpoint, the rear panel CONTROLLER OUTPUT receptacle and front panel FILL LED are energized. When the liquid level subsequently reaches or exceeds the A setpoint, the controller output receptacle is de-energized and the FILL LED is extinguished.

4.1.6 Configure the INTERVAL setting (fill timer) if desired

Model 186 An INTERVAL time-out of up to 600 minutes is provided to alleviate the possibility of liquid overflow. The time-out feature is enabled when the instrument is operated in the AUTO mode with an INTERVAL setting > 0. Once the liquid level falls below the B setpoint, an internal fill timer (whose period is the INTERVAL setting) begins to count down. If the liquid level does not reach the A setpoint before the timer expires, the display will flash rapidly and power to the rear panel CONTROLLER OUTPUT receptacle will be interrupted. To reset this function the fill toggle switch must be momentarily placed in the ON position (to complete the filling process manually) or power to the instrument must be momentarily turned off.

Note

The INTERVAL function is disabled when the INTERVAL setting is "0.0". Adjusting the INTERVAL setting to "0.0" will also terminate any in-progress functions of the INTERVAL timer.

The INTERVAL setting can be adjusted by placing the control mode rotary switch in the INTERVAL position and using the RAISE/LOWER toggle switch to adjust the setting up or down. The display will move slowly at first and then faster. Once near the desired value which is displayed in minutes, simply release the switch momentarily and then resume changing the setpoint at the slower speed. The instrument is shipped from the factory with a zero interval time.

4.1.7 Select the appropriate units display option

Place the units mode toggle switch in the position desired for the display output units during operation. The % position displays the percentage of active sensor length that is immersed in liquid.

4.1.8 Connect the optional analog output signal

If the instrument was purchased with an analog output option, the auxiliary connector J2 on the rear of the instrument provides a 0-10 VDC or 4-20 mA analog signal corresponding to 0-100% of liquid level. Refer to the *Appendix* for the pinout diagram of connector J2.

4.2 Sensor Contamination

To ensure proper instrument calibration and operation, care must be taken to ensure the sensor is kept free of contaminants and not subjected to any force which would physically distort the sensor. Water or other electrically conducting substances in the sensor will disturb the measured capacitance and therefore instrument response. Physically distorting the sensor in any way will also cause abnormal instrument operation by introducing variations in the sensor capacitance not due to liquid level. The absolute calibration of the instrument can be inaccurate if care is not taken to ensure the sensor is in a proper environment.

Cold sensors exposed to humidified air can show erroneous high level readings due to the fact that the air contains moisture which can condense between the cold sensing tubes. A small film of water can cause a shorted or partially shorted condition, which results in false level readings. As the sensor warms, the moisture may evaporate and the sensor will again read correctly. This is a physical phenomenon and does not indicate any problem with your AMI level equipment. Limit or eliminate exposure of cold sensors to humidified air to avoid this condition.

If a sensor should require cleaning, flushing with alcohol is recommended. The sensor cannot be used again until all the alcohol has been evaporated. Under no circumstances should the sensor be disassembled.

5 Remote Interface Reference

5.1 Serial Communication/Data Logger Option

The serial communication/data logger option provides a 25-pin D-type connector on the rear panel of the instrument for serial communications and data logger function.

5.1.1 Serial port connector and cabling

An IBM-compatible computer's serial port can be directly connected to the Model 185/186 via a standard PC modem cable. Refer to your computer's documentation to determine which serial ports are available on your computer and the required connector type. The cable to connect two DB25 connectors is wired directly, i.e. pin 1 to pin 1, pin 2 to pin 2, etc. If a DB9 connector is required at the computer interface, the connector translation is provided in the Appendix.

The Model 185/186 uses only three wires of the rear-panel DB25 connector: pin 2 (transmit), pin 3 (receive), and pin 7 (common). There is no software or hardware handshaking. The Model 185/186 is classified as a DCE (Data Communication Equipment) device since it transmits data on pin 3 and receives data on pin 2. The instrument to which the Model 185/186 is attached must do the opposite, i.e., transmit on pin 2 and receive on pin 3 (the requirements for a DTE, or Data Terminal Equipment device). If a serial-to-parallel converter is used, it must be capable of receiving data on pin 3 or the cable connected to the Model 185/186 must interchange the wires between pins 2 and 3.

Optional RS-422 connector pinout is provided on page 69.

5.1.2 Command/return termination characters

All commands are transmitted and received as ASCII values and are case insensitive. The Model 185/186 always transmits *<CR><LF>* (i.e. a *carriage return* followed by a *linefeed*) at the end of an serial transmission. The Model 185/186 can accept *<CR>*, *<LF>*, *<CR><LF>*, or *<LF><CR>* as termination characters from an external computer.

The simplest method for communicating with the Model 185/186 via RS-232 is by using the interactive mode of a commercially available terminal emulation program. The Model 185/186 transmits and receives information at various baud rates and uses 8 data bits, no parity, and 1 stop bit. When the Model 185/186 receives a terminated ASCII string, it always sends back a reply as soon as the string is processed. *When sending commands to the Model 185/186, you must wait for the reply from the Model 185/186 before sending another command even if the reply consists* *of only termination characters.* Otherwise, the shared input/output command buffer of the Model 185/186 may become corrupted.

5.1.3 Serial Communication DIP Switch Settings

The 8 DIP switches located on the rear panel of the Model 185/186 are used to control various parameters of the RS-232 interface. Switches 6 through 8 control the baud rate of the interface. Switches 3 through 5 control the time interval between data output if the data logger function is enabled. Switch 2 controls the echo feature and switch 1 enables the data logger function. Each of these features is fully discussed below.

5.1.3.1 Baud rate control

The Model 185/186 baud rate is controlled by switches 6 through 8 of the communication DIP switch on the rear panel. The unit is shipped with the baud rate set at 9600. The switch settings for various baud rates are (on = 1 or the up position):

DIP switch			Baud rate
6	7	8	
off	off	off	300
off	off	on	600
off	on	off	1200
off	on	on	2400
on	off	off	4800
on	off	on	9600

5.1.3.2 Echo function

The Model 185/186 has an *echo* feature which is enabled or disabled by communication DIP switch 2. When the echo function is enabled, the Model 185/186 will echo the incoming command characters back to the transmitting device. The echo feature is useful when using an interactive terminal program on a host computer for communicating with the Model 185/186. The settings are:

DIP switch 2	Function
on	Echo On
off	Echo Off

5.1.3.3 Data logger function

Switch 1 of the communications DIP switch controls the data logger function. The unit is shipped with the data logger function disabled. This feature is normally used with a printer rather than a host computer, since a computer can be more usefully programmed utilizing the available command set. The data logger function generates a time relative to instrument power-up and a corresponding level. The units of the level output are set by the units mode toggle switch. The time and corresponding level are formatted and output to the host device at regular intervals as specified by the switches 3 through 5. The settings for the data logger function are:

DIP switch 1	Function
on	Data Logger On
off	Data Logger Off

The host device can be a standard dot matrix printer connected via a serial-to-parallel converter, or connected directly with a printer capable of receiving serial data. Presumably, any serial-to-parallel converter which can be properly configured is acceptable. AMI has tested the Model 185/186 with a standard, low cost converter configured as a DTE device, 8 data bits, no parity, and 1 stop bit. In order to communicate with the host device, it is necessary to set the Model 185/186 to the identical baud rate of the host device.

5.1.3.4 Data logger output interval

The interval between successive output from the data logger function is controlled by switches 3 through 5. The unit is shipped with the *data logger function* disabled (see above). The available intervals and the corresponding switch settings are (on = 1 or the up position):

DIP switch			Interval (minutes)
3	4	5	
off	off	off	1
off	off	on	2
off	on	off	5
off	on	on	10
on	off	off	20
on	off	on	30
on	on	off	60

5.1.4 Serial Command Set Reference

All commands sent to the Model 185/186 are processed and the Model 185/186 responds with a return value (if applicable) and termination. If the command is invalid, the Model 185/186 will respond with an error code (see the *Error Codes* section). All return values including error codes are terminated with *<CR><LF>* (i.e. a *carriage return* followed by a *linefeed*). For those commands that do not return a value, the Model 185/186 will return the *<CR><LF>* termination only.

5.1.4.1 Commands for controlling the units of measurement

Command:	CM	Function:	Sets the units of measurement to centimeters	Returns:	<CR><LF>
Command:	INCH	Function:	Sets the units of measurement to inches	Returns:	<CR><LF>
Command:	PERCENT	Function:	Sets the measurement to % of sensor length	Returns:	<CR><LF>
Command:	UNIT	Function:	Returns the current units in use	Returns:	C, I, or % <CR><LF>

The CM command sets the units of measurement to centimeters and the INCH command selects inches. The PERCENT command sets the units of measurement to the percentage of active sensor length that is immersed in liquid. **The units of measurement selected through the serial interface are controlled independently from the units mode toggle switch used for controlling the front panel display.** The remote units setting is saved in permanent memory by the SAVE command and is restored at power-up. The UNIT command returns a one character value (and termination) indicating the current units—C for centimeters, I for inches, or % for percentage.

5.1.4.2 Commands for configuring permanent memory

	Command:	HI=*<value>*	**Function:**	Configures the HI setpoint limit	**Returns:**	<CR><LF>
	Command:	LO=*<value>*	**Function:**	Configures the LO setpoint limit	**Returns:**	<CR><LF>
Model 186	**Command:**	A=*<value>*	**Function:**	Configures the A setpoint (control band upper limit)	**Returns:**	<CR><LF>
Model 186	**Command:**	B=*<value>*	**Function:**	Configures the B setpoint (control band lower limit)	**Returns:**	<CR><LF>
Model 186	**Command:**	INTERVAL= *<value>*	**Function:**	Configures the fill timer in minutes	**Returns:**	<CR><LF>
	Command:	LENGTH=*<value>*	**Function:**	Configures the active sensor length	**Returns:**	<CR><LF>
	Command:	SAVE	**Function:**	Saves the configuration to permanent memory	**Returns:**	<CR><LF>

The HI and LO command configure the high and low setpoint limit values respectively. For example, HI=90.0 would configure the high setpoint limit to 90.0 in whichever units of measurement last selected through the serial interface. The A and B commands configure the upper limit and lower limit of the control band, respectively. The HI, LO, A, and B commands are compatible with the percent units selection.

The LENGTH command configures the active sensor length setting in the current units. LENGTH=35.0 would configure the active sensor length to 35.0 units of centimeters or inches.

Note

The LENGTH=<value> command will only function if CM or INCH are currently selected as the units of measurement. The LENGTH command does not configure the Model 185/186 if the units of measurement are PERCENT.

The INTERVAL command sets the fill timer in minutes as described in the *Operation* section on page 32. Setting the value of INTERVAL to 0 disables the fill timer function.

The SAVE command saves the HI, LO, A, B, INTERVAL, LENGTH, and current remote units settings to permanent memory. Saved settings are then recalled each time the power is turned off and then reapplied to the instrument. If the configuration is changed from the front panel, the settings are automatically saved to permanent memory.

5.1.4.3 Commands for querying the configuration

	Command:	HI	**Function:**	Returns the HI setpoint limit in the current units	**Returns:**	<value> <CR><LF>
	Command:	LO	**Function:**	Returns the LO setpoint limit in the current units	**Returns:**	<value> <CR><LF>
Model 186	**Command:**	A	**Function:**	Returns the A setpoint limit in the current units	**Returns:**	<value> <CR><LF>
Model 186	**Command:**	B	**Function:**	Returns the B setpoint limit in the current units	**Returns:**	<value> <CR><LF>
Model 186	**Command:**	INTERVAL	**Function:**	Returns the fill timer setting in minutes	**Returns:**	<value> <CR><LF>
	Command:	LENGTH	**Function:**	Returns the active sensor length in the current units	**Returns:**	<value> <CR><LF>

The HI, LO, A, B, INTERVAL, and LENGTH commands return the current configuration of the instrument. Each return value is terminated with *<CR><LF>*.

5.1.4.4 Command for returning a level measurement

Command:	LEVEL	**Function:**	Returns the liquid level in the current units	**Returns:**	<value> <CR><LF>

The LEVEL command returns the liquid level in the current units selected through the communication interface.

5.1.4.5 Commands for performing remote calibration

Command:	MINCAL	**Function:**	Performs a MIN calibration	**Returns:**	<CR><LF>

Command:	MAXCAL	**Function:**	Performs a MAX calibration	**Returns:**	<CR><LF>

Command:	APPROX= *<value>*	**Function:**	Performs an approximate calibration using *value* as the approximate calibration factor	**Returns:**	<CR><LF>

The calibration commands perform a remote calibration equivalent to activating the front panel MIN, MAX, and "~" (approximate) calibration buttons. The calibration is automatically saved to permanent memory. See the *Calibration* section for more information regarding calibration.

5.2 IEEE-488 Communication Option

The IEEE-488 communication option provides a GPIB connector on the rear panel of the instrument for IEEE-488 (GPIB, HPIB) communications.

5.2.1 Command/return termination characters

All commands are transmitted and received as ASCII values and are case insensitive. The Model 185/186 always transmits <LF> and EOI as the termination for return data. The Model 185/186 can accept *<CR>*, *<LF>*, *<CR><LF>*, *<LF><CR>*, or *<LF>* with EIO as termination characters from an external IEEE-488 interface.

Only one command at a time should be sent to the Model 185/186 by the external IEEE-488 interface. Additional commands separated by a semicolon will not be processed. The instrument uses a single 16 character buffer for input and output. Consequently, all input strings including terminations should not be longer than 16 characters. Any excess characters will be discarded. All alphabetical characters are case insensitive and character encoding is in accordance with IEEE 488.2.

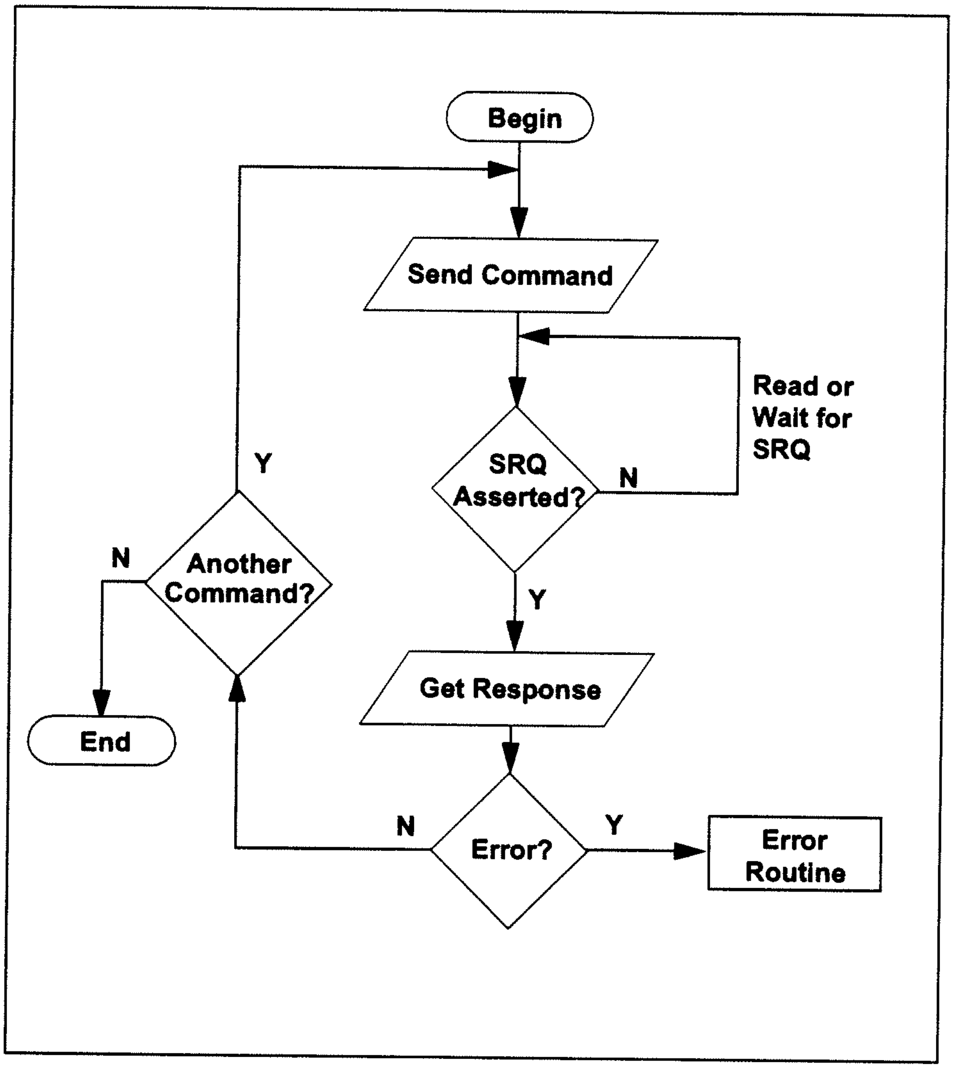
5.2.2 Communicating with the Model 185/186

The use of a single buffer for both input and output is a result of memory limitations in the Model 185/186. In order to keep the external IEEE-488 interface from sending successive commands faster than the Model 185/186 can respond, the Model 185/186 uses the Serial Poll Service Request (SRQ) to let the external computer know it has finished processing the last command received and is ready to send a response. This is true of all commands. Thus sending commands to the Model 185/186 using IEEE-488 protocol is a three step process: 1) send the ASCII command, 2) wait for SRQ, and 3) get the instrument response.

Note

API's for some manufacturer's cards require you to use different functions to check for SRQ and read the serial poll status (spoll) byte. Invoking the command to read the spoll byte may be required to actually clear the SRQ status.

A basic flow diagram for sending an ASCII command to the Model 185/186 and receiving a response is shown on the following page. It is not necessary to wait exclusively for the SRQ status from the instrument. Other bus commands can be processed while waiting for the SRQ status from the instrument.



Basic communication flow diagram for IEEE-488 commands.

5.2.3 IEEE-488 Communication DIP Switch Settings

The 5 DIP switches located on the rear panel of the Model 185/186 are used to set the primary IEEE-488 bus address of the unit.

5.2.3.1 IEEE-488 primary bus address

The Model 185/186 primary bus address is controlled by switches 1 through 5 of the communication DIP switch on the rear panel. Valid primary addresses are between 0 and 30. The Model 185/186 does not use secondary addressing. Note that many IEEE-488 controller cards in external computers will use address 0 (or 21). The bus address for each Model 185/186 *should be unique* with respect to other Model 185/186 units or any other devices on the bus. The switch settings for the various addresses are (on = 1 or the up position):

DIP switch					Primary bus address
1	2	3	4	5	
off	off	off	off	off	0
off	off	off	off	on	1
off	off	off	on	off	2
off	off	off	on	on	3
off	off	on	off	off	4
off	off	on	off	on	5
off	off	on	on	off	6
off	off	on	on	on	7
off	on	off	off	off	8
off	on	off	off	on	9
off	on	off	on	off	10
off	on	off	on	on	11
off	on	on	off	off	12
off	on	on	off	on	13
off	on	on	on	off	14
off	on	on	on	on	15
on	off	off	off	off	16
on	off	off	off	on	17
on	off	off	on	off	18

DIP switch					Primary bus address
1	2	3	4	5	
on	off	off	on	on	19
on	off	on	off	off	20
on	off	on	off	on	21
on	off	on	on	off	22
on	off	on	on	on	23
on	on	off	off	off	24
on	on	off	off	on	25
on	on	off	on	off	26
on	on	off	on	on	27
on	on	on	off	off	28
on	on	on	off	on	29
on	on	on	on	off	30

5.2.4 IEEE-488 Command Set Reference

All commands sent to the Model 185/186 are processed and the Model 185/186 responds with a return value and termination. If the command is invalid, the Model 185/186 will respond with an error code (see the *Error Codes* section). All return values including error codes are terminated with *<LF>* (*linefeed*) and EOI asserted. For those commands that do not return a value, the Model 185/186 will echo the command string in the return message. The Model 185/186 does not implement a full complement of IEEE 488.2 commands, nor does it conform to the Standard Commands for Programmable Instruments (SCPI) protocol. These limitations are due to memory constraints in the microprocessor board design.

5.2.4.1 Device clear (DCL) command

The Model 185/186 responds to the device clear (DCL) command from a host IEEE controller. The device clear resets the instrument. The default communications interface units are centimeters and the permanently saved configuration settings are restored.

5.2.4.2 Commands for controlling the units of measurement

Command:	CM	**Function:**	Sets the units of measurement to centimeters	**Returns:**	CM
Command:	INCH	**Function:**	Sets the units of measurement to inches	**Returns:**	INCH
Command:	PERCENT	**Function:**	Sets the measurement to % of active sensor length	**Returns:**	%
Command:	UNIT	**Function:**	Returns the current units in use	**Returns:**	C, I, or %

The CM command sets the units of measurement to centimeters and the INCH command selects inches. The PERCENT command sets the units of measurement to the percentage of the active sensor length that is immersed in liquid. **The units of measurement selected through the IEEE-488 interface are controlled independently from the units mode toggle switch used for controlling the front panel display.** The remote units setting is saved in permanent memory by the SAVE command and is restored at power-up. The UNIT command returns a one character value (and termination) indicating the current units—C for centimeters, I for inches, or % for percentage.

5.2.4.3 Commands for configuring permanent memory

	Command:		Function:		Returns:	
	Command:	HI=*<value>*	Function:	Configures the HI setpoint limit	Returns:	HI=*<value>*
	Command:	LO=*<value>*	Function:	Configures the LO setpoint limit	Returns:	LO=*<value>*
Model 186	Command:	A=*<value>*	Function:	Configures the A setpoint (upper limit of control band)	Returns:	A=*<value>*
Model 186	Command:	B=*<value>*	Function:	Configures the B setpoint (lower limit of control band)	Returns:	B=*<value>*
Model 186	Command:	INTERVAL= *<value>*	Function:	Configures the fill timer in minutes	Returns:	INTERVAL= *<value>*
	Command:	LENGTH= *<value>*	Function:	Configures the active sensor length	Returns:	LENGTH= *<value>*
	Command:	SAVE	Function:	Saves the configuration to permanent memory	Returns:	SAVE

The HI and LO command configure the high and low setpoint limit values respectively. For example, HI=90.0 would configure the high setpoint limit to 90.0 in whichever units of measurement last selected through the IEEE-488 interface. The A and B commands configure the upper limit and lower limit of the control band, respectively. The HI, LO, A, and B commands are compatible with the percent units selection.

The LENGTH command configures the active sensor length setting in the current units. For example, LENGTH=35.0 would configure the active sensor length to 35.0 units of centimeters or inches.

Note

The LENGTH=<value> command will only function if CM or INCH are currently selected as the units of measurement. The LENGTH command does not configure the Model 185/186 if the units of measurement are PERCENT.

The INTERVAL command sets the fill timer in minutes as described in the *Operation* section on page 32. Setting the value of INTERVAL to 0 disables the fill timer function.

The SAVE command saves the HI, LO, A, B, INTERVAL, LENGTH, and current remote units settings to permanent memory. Saved settings are then recalled each time the power is turned off and then reapplied to the instrument. If the configuration is changed from the front panel, the settings are automatically saved to permanent memory.

5.2.4.4 Commands for querying the configuration

	Command:	HI	**Function:**	Returns the HI setpoint limit in the current units	**Returns:**	*<value>*
	Command:	LO	**Function:**	Returns the LO setpoint limit in the current units	**Returns:**	*<value>*
Model 186	**Command:**	A	**Function:**	Returns the A setpoint limit in the current units	**Returns:**	*<value>*
Model 186	**Command:**	B	**Function:**	Returns the B setpoint limit in the current units	**Returns:**	*<value>*
Model 186	**Command:**	INTERVAL	**Function:**	Returns the fill timer setting in minutes	**Returns:**	*<value>*
	Command:	LENGTH	**Function:**	Returns the sensor length in the current units	**Returns:**	*<value>*

The HI, LO, A, B, INTERVAL, and LENGTH commands return the current configuration of the instrument. Each return value is terminated with *<LF>* and EOI.

5.2.4.5 Command for returning a level measurement

Command:	LEVEL	**Function:**	Returns the liquid level in the current units	**Returns:**	*<value>*

The LEVEL command returns the liquid level in the current units selected through the communication interface.

6 Virtual Instrument Operation

In order to make the communications options easier to use for the customer, AMI provides a LabVIEW-based interface for remote monitoring and control of the Model 185/186. LabVIEW® is a virtual instrument (VI) development and deployment software tool produced and marketed by National Instruments. LabVIEW is available on several platforms including Microsoft Windows™, Microsoft Windows NT™, Apple Macintosh™, Sun Solaris™, and HP-UX™. The AMI provided VI's are developed and tested under Microsoft Windows 3.1 and 3.11, however, they should be portable with only minor modifications across all LabVIEW-supported platforms. Please contact National Instruments for detailed information on the available products and specifications.

The AMI provided VI's are supplied on one 3.5" 1.44 MB diskette. ***The VI's require version 3.1 (or above) of LabVIEW and a minimum of a 256 color display.*** The VI's are stored in one LabView VI Library (LLB) file which contains the multiple VI's needed for operation of the instrument as a whole. AMI's provided VI's are designed for continuous operation under the control of LabVIEW, and do not conform to the instrument driver specifications to which National Instruments' own instrument drivers adhere. Any additional functionality gained by conforming to such specifications was deemed of minimal value by AMI due to the relative simplicity of communicating with the Model 185/186 instrument.

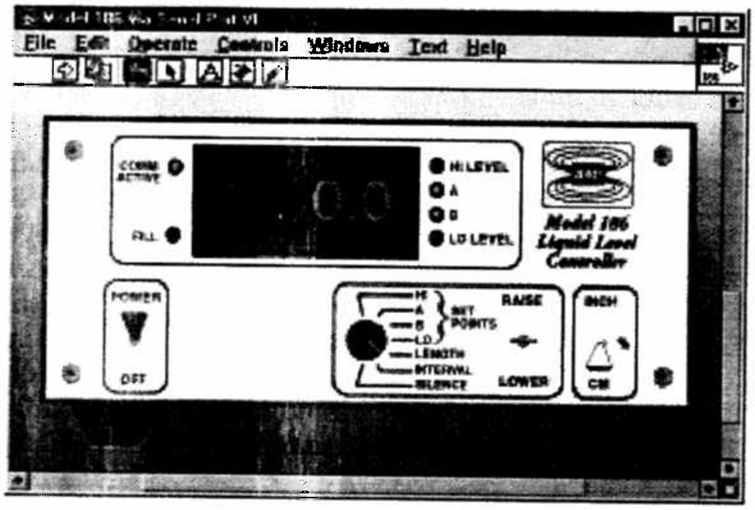
Note

Virtual instrument names which are common to both the Model 185 and Model 186 drivers are noted as "18X" in this section. The actual model number "185" or "186" is used in the LabVIEW VI's.

6.1 RS-232 Virtual Instrument

The figure below illustrates the front panel of the Model 186 virtual instrument (VI). The front panel appears nearly identical to the front panel of the actual instrument. The functionality of the VI is very similar to that of the actual instrument as well.

When running the VI it is important to operate the instrument using the VI and not via the actual instrument front panel. Otherwise, the VI and the actual instrument may not be synchronized. The only exceptions to this rule are calibration procedures or operation of the fill toggle switch if manual override becomes necessary, both of which are functions that are not available from the VI. Any function available from the VI should be normally be set by using the VI and not the front panel of the instrument.



6.1.1 Launching and initializing the RS-232 VI

First, make sure the Model 185/186 is connected to a COM port on the host computer and that the instrument is powered on. The VI library, provided in the file MODEL18X.LLB, for the RS-232 virtual instrument contains the following files:

	VI	Function
	18X Alarms.vi	Manages alarm functions for 185/186.
	Config 18X via Serial Port.vi	Initializes actual instrument from VI configuration.
	Convert from CM.vi	Displays inches or percentage given input in cm.
	Counter.vi	Timer function for the virtual display.
	Get 18X Level via Serial Port.vi	Updates virtual display with current level.
	Init from 18X via Serial Port.vi	Initializes VI configuration from actual instrument.
	Model 18X via Serial Port.vi	The main VI containing the configuration and front panel controls. This is the VI the user should open and execute.
	Serial Port Send.vi	Manages sending and receiving of ASCII strings from the actual instrument.
Model 186	Set 186 A via Serial Port.vi	Configures the A setpoint.
Model 186	Set 186 B via Serial Port.vi	Configures the B setpoint.

5.2.4.6 Commands for performing remote calibration

Command:	MINCAL	Function:	Performs a MIN calibration	Returns:	MINCAL
Command:	MAXCAL	Function:	Performs a MAX calibration	Returns:	MAXCAL
Command:	APPROX= <*value*>	Function:	Performs an approximate calibration using <*value*> as the approximate calibration factor	Returns:	APPROX = <*value*>

The calibration commands perform a remote calibration equivalent to activating the front panel MIN, MAX, and "~" (approximate) calibration buttons. The calibration is automatically saved to permanent memory. See the *Calibration* section for more information regarding calibration.

5.2.5 Serial poll status byte

The IEEE-488 serial poll status byte (spoll byte) can be used to obtain information about the state of the instrument. Bit 7 of the status byte is reserved for SRQ. The remaining bits are used to provide custom information as shown in the table below.

	Bit	ON	OFF
	1 (LSB)	HI relay on	HI relay off
Model 186	2	A relay on	A relay off
Model 186	3	B relay on	B relay off
	4	LO relay on	LO relay off
Model 186	5	Fill mode on (controller output energized)	Fill mode off (controller output de-energized)
	6	Data ready	No data available
	7	Service Request (SRQ)	No SRQ
	8	Not used	Not used

Note

The fill mode indication is only accurate if the fill mode toggle switch on the front panel is in the AUTO position. There is no remote indication or control available for the OPEN or CLOSED manual override selections.

5.3 Error Codes

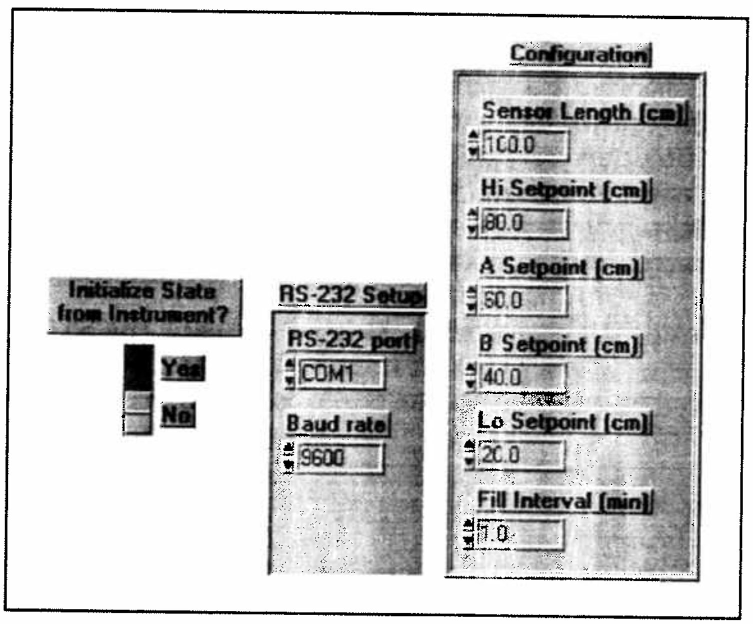
The Model 185/186 returns specific error codes for invalid commands and/or arguments. If an error condition is returned, the command is not processed and the configuration of the instrument is *not* modified. The table below provides a list of error codes, their meaning, and any associated limits.

	Error Code	Meaning	Valid Range
	−1	LO setpoint out of range	0 ≤ LO ≤ LENGTH
Model 186	−2	B setpoint out of range	0 ≤ B < A
Model 186	−3	A setpoint out of range	B < A ≤ LENGTH
	−4	HI setpoint out of range	0 ≤ HI ≤ LENGTH
	−5	Attempted to set or query for LENGTH in PERCENT units mode	
	−6	Invalid argument, *value* out of maximum calibration range	1 cm ≤ *value* ≤ 650 cm
Model 186	−7	INTERVAL setting out of range	0 ≤ INTERVAL≤ 600 min
	−8	Unrecognized command	
	−9	Invalid argument, *value* was negative or non-numeric	
	−0	Approximate calibration *factor* out of range	0.1 ≤ *factor* ≤ 999.9

Model 186

VI	Function
Set 186 Fill via Serial Port.vi	Configures the fill interval setting.
Set 18X HI via Serial Port.vi	Configures the HI setpoint.
Set 18X Length via Serial Port.vi	Configures the active sensor length.
Set 18X LO via Serial Port.vi	Configures the LO setpoint.

Open the *Model 18X via Serial Port.vi.* Before running the VI, the user must select an initialization option and provide any necessary settings. In order to initialize the VI, scroll to the area above the virtual front panel. Several controls are visible for setup by the user. The figure below illustrates the available controls. The *Initialize State from Instrument?* switch allows the user to select whether the instrument is initialized from the current settings of the actual instrument or from the controls available from the VI. If the *Yes* option is selected, the VI will initialize all settings from the actual instrument. If the *No* option is selected, the user should enter all data in the control fields (*Sensor Length, Hi Setpoint*, etc.) in the indicated units. The user should also select the correct RS-232 port and



baud rate, according to the port to which the Model 185/186 is connected and the baud rate to which the instrument is set (see page 36 for instructions on setting the Model 185/186 baud rate). The user may then start the VI. Please refer to your LabVIEW documentation for instructions on how to start and control the execution of VI's.

6.1.2 Interacting with the running VI

While the VI is running the user may manipulate the virtual toggle and rotary switches in the same manner as required for the front panel operation of the actual instrument. See the *Operation* section of this manual for instructions on operating the front panel controls, however, please note that there are some minor differences discussed below.

The RAISE/LOWER toggle switch functions slightly different in the VI. If the RAISE/LOWER toggle switch is moved from the center position to the RAISE or LOWER position, then the display changes to show the appropriate parameter. After approximately 4 seconds in the RAISE or LOWER position, the display will begin incrementing or decrementing by tenths. After approximately 12 additional seconds, the display will begin incrementing/decrementing by ones. Move the RAISE/LOWER toggle switch back to the center position to stop the incrementing or decrementing function.

The virtual instrument's FILL LED indicator is only accurate if the fill toggle switch is in the AUTO position. There is no remote monitoring or control of the manual override states of the fill toggle switch available through the communication command set.

As a more convenient option for controlling the settings, the user may scroll to the area above the VI and enter the values for the Sensor Length, Hi Setpoint, A Setpoint, B Setpoint, Lo Setpoint, and Fill Interval directly in the control fields (please observe the specified units). Any changes in the fields are recognized and sent to the actual instrument in the form of the appropriate command string. Any settings changed by the VI virtual panel toggle switches or control fields are saved in permanent memory in the actual instrument.

The VI may be gracefully stopped by using the STOP toggle switch in the lower left corner of the VI. After stopping the VI, this switch must be placed back in the up position in order to restart the VI.

6.2 IEEE-488 Virtual Instrument

The IEEE-488 (or GPIB) VI functions nearly identically to the RS-232 VI with a few exceptions. The VI library, provided in the file MODEL18X.LLB, for the IEEE-488 virtual instrument contains the following files:

	VI	Function
	18X Alarms.vi	Manages alarm functions for 185/186.
	Config 18X via GPIB.vi	Initializes actual instrument from VI configuration.
	Convert from CM.vi	Displays inches or percentage given input in cm.
	Counter.vi	Timer function for the virtual display.
	Get 18X Level via GPIB.vi	Updates virtual display with current level.
	Init from 18X via GPIB.vi	Initializes VI configuration from actual instrument.
	Model 18X via GPIB.vi	The main VI containing the configuration and front panel controls. This is the VI the user should open and execute.
	Non-exclusive loop control.vi	This VI, *which is only available in the COMP18X.LLB library*, should be modified and executed for non-exclusive GPIB operation.
	GPIB Send.vi	Manages sending and receiving of ASCII strings from the actual instrument.
Model 186	Set 186 A via GPIB.vi	Configures the A setpoint.
Model 186	Set 186 B via GPIB.vi	Configures the B setpoint.
Model 186	Set 186 Fill via GPIB.vi	Configures the fill interval setting.
	Set 18X HI via GPIB.vi	Configures the HI setpoint.
	Set 18X Length via GPIB.vi	Configures the active sensor length.
	Set 18X LO via GPIB.vi	Configures the LO setpoint.

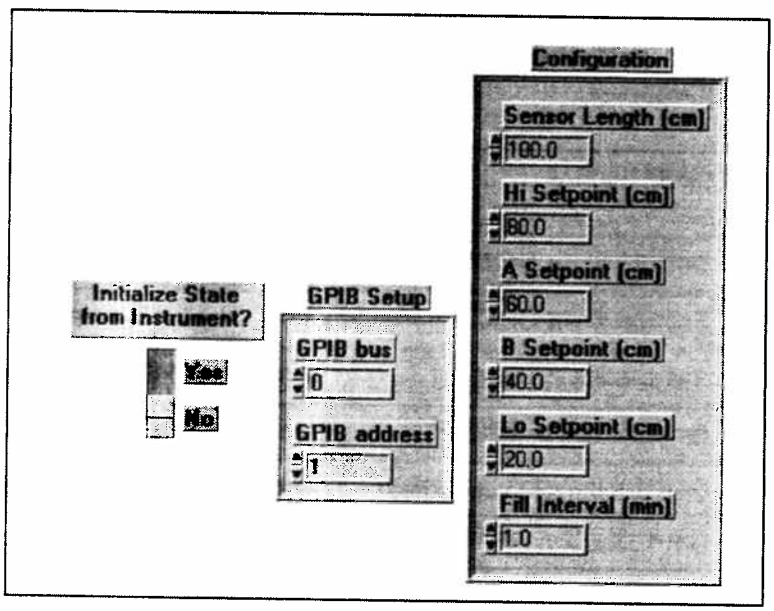
The *Model 18X via GPIB.vi* in the MODEL18X.LLB library should be used if the Model 185/186 has exclusive control of the GPIB bus, i.e. is the only device queried on the bus.

An additional library provided on the LabVIEW floppy disk, COMP18X.LLB, contains all the VI's included in the MODEL18X.LLB library along with the additional *Non-exclusive loop control.vi* and reusable version of the *Model 18X via GPIB.vi*. The *Non-exclusive loop control.vi* provides a control example which can be customized to coexist with multiple devices on one GPIB bus. The exact design of the non-exclusive operation is dependent upon the specific devices you may have connected to the bus.

When running a VI it is important to operate the instrument using the VI and not via the actual instrument front panel. Otherwise, the VI and the actual instrument may not be synchronized. The only exceptions to this rule are calibration procedures or operation of the fill toggle switch if manual override becomes necessary, both of which are functions that are not available from the VI. Any function available from the VI should be normally be set by using the VI and not the front panel of the instrument.

6.2.1 Launching and initializing the GPIB VI

First, make sure the Model 185/186 is connected to the GPIB bus and that the unit is powered on. Independent of whether you use the exclusive or non-exclusive mode of execution, the initialization method of the Model 185/186 should be determined. To set the initialization method, scroll to the area above the virtual front panel and observe the virtual controls as illustrated below (the version of the *Model 18X via GPIB.vi* provided in COMP18X.LLB provides inputs for the initialization method and input/output for the configuration). The *Initialize State from Instrument?* switch



allows the user to select whether the instrument is initialized from the current settings of the actual instrument or from the controls available from the VI. If the *Yes* option is selected, the VI will initialize all settings from the actual instrument. If the *No* option is selected, the user should enter all data in the control fields (*Sensor Length, Hi Setpoint*, etc.) in the indicated units. The user should also select the correct GPIB bus and primary address (see page 44 for instructions on setting the Model 185/186 primary address). If only one GPIB interface is present in the host computer, the GPIB bus is normally set to 0. Refer to your LabVIEW documentation for more information on how to determine the GPIB bus setting appropriate for your computer. After setting the initialization parameters, the user may then start the VI. Please refer to your LabVIEW documentation for instructions on how to start and control the execution of VI's.

6.2.2 Interacting with the running VI

While the VI is running the user may manipulate the virtual toggle and rotary switches in the same manner as required for the front panel operation of the actual instrument. See the *Operation* section of this manual for instructions on operating the front panel controls, however, please note that there are some minor differences discussed below.

The RAISE/LOWER toggle switch functions slightly different in the VI. If the RAISE/LOWER toggle switch is moved from the center position to the RAISE or LOWER position, then the display changes to show the appropriate parameter. After approximately 4 seconds in the RAISE or LOWER position, the display will begin incrementing or decrementing by tenths. After approximately 12 additional seconds, the display will begin incrementing/decrementing by ones. Move the RAISE/LOWER toggle switch back to the center position to stop the incrementing or decrementing function.

The virtual instrument's FILL LED indicator is only accurate if the fill toggle switch is in the AUTO position. There is no remote monitoring or control of the manual override states of the fill toggle switch available through the communication command set.

As a more convenient option for controlling the settings, the user may scroll to the area above the VI and enter the values for the Sensor Length, Hi Setpoint, A Setpoint, B Setpoint, Lo Setpoint, and Fill Interval directly in the control fields (please observe the specified units). Any changes in the fields are recognized and sent to the actual instrument in the form of the appropriate command string. Any settings changed by the VI virtual panel toggle switches or control fields are saved in permanent memory in the actual instrument. The control fields and toggle switches function whether the VI is run exclusively or non-exclusively on the GPIB bus.

If the VI is executed exclusively, then the VI may be gracefully stopped by using the STOP toggle switch in the lower left corner of the VI. After stopping the VI, this switch must be placed back in the up position in order to restart the VI. If you are executing the VI in a non-exclusive polling loop on the GPIB bus, then the STOP toggle switch has no function and the user should control the execution of the VI from the controlling parent VI(s).

6.2.3 Running multiple GPIB devices

The *Model 18X via GPIB.vi* in the MODEL18X.LLB library is designed to have exclusive control of the GPIB bus. AMI recognizes this is generally not the case for a GPIB bus configuration. Therefore, the *Non-exclusive loop control.vi* example is provided in the COMP18X.LLB library to demonstrate how the *Model 18X via GPIB.vi* can be cooperatively executed on a GPIB bus with multiple devices connected.

In order to use multiple devices from the same host computer and GPIB bus, the Model 185/186 should be set to a unique primary address. In addition to modifications required to use other devices present on the bus, the user should modify the *Non-exclusive loop control.vi* to both initialize and then execute the *Model 18X via GPIB.vi* at a regular interval. The longer the interval between execution, the less responsive the VI will appear. This is due to the fact that the VI assumes periodic execution in order to poll the virtual switches and control fields for user-initiated changes. The suggested period between execution is 1 second in order to exhibit a reasonable level of responsiveness from the VI. The requirement to constantly poll a virtual panel for changes is an unfortunate requirement for running these types of continuously executing interfaces using LabVIEW.

7 Service Guide

The procedures in this section should only be performed by Qualified Service Personnel (QSP).

7.1 Troubleshooting Procedures

The following paragraphs serve as an aid to assist QSP in troubleshooting a potential problem with the Model 185/186. If the QSP is not comfortable with troubleshooting the system, you may contact an Authorized AMI Technical Support Representative for assistance. Refer to "Additional Technical Support" on page 66.

This instrument contains CMOS components which are susceptible to damage by Electrostatic Discharge (ESD). Take the following precautions whenever the cover of the instrument is removed.

1. Disassemble the instrument only in a static-free work area.
2. Use a conductive workstation or work area to dissipate static charge.
3. Use a high resistance grounding wrist strap to reduce static charge accumulation.
4. Ensure all plastic, paper, vinyl, Styrofoam® and other static generating materials are kept away from the work area.
5. Minimize the handling of the instrument and all static sensitive components.
6. Keep replacement parts in static-free packaging.
7. Do not slide static-sensitive devices over any surface.
8. Use only antistatic type solder suckers.
9. Use only grounded-tip soldering irons.

7.1.1 No level reading

1. Ensure that the instrument is energized from a power source of proper voltage.

   Warning

   If the instrument has been found to have been connected to an incorrect power source, return the instrument to AMI for evaluation to determine the extent of the damage. Frequently, damage of this kind is not visible and must be determined using test equipment. Connecting the instrument to an incorrect power source could damage the internal insulation and/or the ground requirements, thereby, possibly presenting a severe life-threatening electrical hazard.

2. Verify continuity of the line fuse, F1, located on the instrument printed circuit board.

   Warning

   This procedure is to be performed only when the instrument is completely de-energized by removing the power-cord from the power receptacle. Failure to do so could result in personnel coming in contact with high voltages capable of producing life-threatening electrical shock.

   a. Ensure the instrument is de-energized by disconnecting the power cord from the power source. Disconnect the power cord from the connector located on the rear panel of the instrument.

   b. Remove the instrument top cover and check the fuse F1 for continuity.

   c. If the fuse is bad, replace with a 315 mA IEC 127-2 Type F Sheet II 5x20mm fuse.

   Caution

   Installing fuses of incorrect values and ratings could result in damage to the instrument in the event of component failure.

   d. Replace the fuse and securely fasten the instrument top cover. Reconnect the power-cord.

3. Verify the input voltage selector switch on the instrument's printed circuit board is in the proper position for the available power receptacle at the customer's facility. Checking the input voltage

selector requires removal of the top cover of the instrument. Observe the same safety procedures as presented in step 2.

7.1.2 Erratic or erroneous level reading

1. Verify that the sensor is properly connected to the oscillator cable and the extension cable (see the system diagram on page 7).

2. Verify the cabling has no breaks or cuts.

3. If the Model 185/186 suddenly reads 100% without a corresponding level, there is a possibility of moisture in the connector at the top of the sensor. Disconnect the BNC connection and remove any moisture. Moisture or contaminants in any of the BNC coaxial connectors can short out the sensor and cause a false 'full' level indication or other erroneous readings. A pack of non-conductive electrical connection lubricant (ECL or "Dielectric Tune-up Grease") has been included with the liquid level sensor packaging to reduce the possibility of this occurring. Apply a small amount of ECL to any of the BNC connectors that may be exposed to moisture. Mate the doped connectors then remove any excess ECL from the outside of the connector. Added protection can be achieved by covering the doped connections with a short section of heat-shrink tubing.

   Note: MSDS sheets for the ECL are available upon request.

4. Ensure the oscillator unit is not exposed to large temperature gradients such as those that occur near dewar vents. Extreme temperature changes of the oscillator unit can cause readout errors.

5. Rapidly varying or sloshing liquids will sometimes make one think the instrument is in error when it is actually operating properly.

6. Capacitance-based sensors used in cryogenic liquid systems are sometimes exposed to humidified air when the cryogenic vessel is emptied. This often happens when a cold trap runs out of liquid. As the sensor warms, the electronics can show large errors (readings greater than 20% are not uncommon). This is due to the fact that air contains moisture which will condense between the cold sensing tubes. This small film of moisture can cause a shorted or partially shorted condition. The electronics may recognize this as a higher level reading and display some positive level. As the sensor warms over some period of time, the moisture can evaporate and the sensor will again approach the correct reading of 0%. This condition can also be corrected immediately if liquid nitrogen is added to the cold trap freezing the residual moisture. This is a physical phenomenon and does not indicate any problem with your AMI level equipment.

7. Verify the sensor is free of contaminants and not subject to any physical distortion. Disconnect the BNC connector at the top of the sensor and measure the sensor resistance by placing an ohmmeter across the center pin and the outer barrel of the connector. The resistance of the sensor should typically be >10 MΩ.

7.1.3 Controller output does not energize

Warning

This procedure is to be performed only when the instrument is completely de-energized by removing the power-cord from the power receptacle. Failure to do so could result in personnel coming in contact with high voltages capable of producing life-threatening electrical shock.

1. Verify continuity of controller output fuses, F2 and F3, located on the instrument printed circuit board.

   a. Ensure the instrument is de-energized by disconnecting the power cord from the power source. Disconnect the power cord from the connector located on the rear panel of the instrument.

   b. Remove the instrument top cover and check the fuses F2 and F3 for continuity.

   c. If a fuse is bad, replace with a 2.5A IEC 127-2 Type F Sheet II 5x20mm fuse.

   d. Check your connected equipment for compliance with the output receptacle rating.

Caution

Installing fuses of incorrect values and ratings could result in damage to the instrument in the event of component failure.

2. Replace the fuse and securely fasten the instrument top cover. Reconnect the power-cord.

7.1.4 Unit not responding to communications

1. Verify your communications cable integrity and wiring. See the *Appendix* for DB-25 to DB-9 translation for RS-232 cables.

2. Check to make sure you are sending the correct termination to the instrument. If you are using the serial option, make sure the echo feature is set correctly for your application and the baud rate matches the setting of the host device. If you are using the IEEE-

488 option, check the primary address setting and make sure the controller software is set to query the instrument at the primary address selected.

3. Check your host communications software and make sure it is recognizing the return termination characters from the instrument. For serial communication, the return termination characters are *<CR><LF>*. For IEEE-488, the return message termination characters are *<LF>* with EOI.

4. If the instrument is responding repeatedly with *-8* as the return message, try a device clear command (DCL) or powering the instrument off and then back on. Be sure you are sending valid commands.

5. If you experience continued trouble with the IEEE-488 option, you may have an incompatible IEEE-488 card in your host computer. In the past, AMI has found subtle differences between manufacturers of IEEE-488 cards that have introduced communication errors. AMI attempts to establish compatibility with as many products as possible, however it is difficult to test every card available. Contact AMI directly if you have thoroughly checked your setup and continue to experience problems with the IEEE-488 option.

6. Version 2.6 of the NI-488.2 drivers from National Instruments has known bugs that prevent the correct operation of the IEEE-488 interface when executed from LabVIEW. Contact National Instruments for workarounds appropriate for your configuration.

If the cause of the problem cannot be located, contact an AMI customer service representative at (865) 482-1056 for assistance. Do not send the unit back to AMI without prior return authorization.

7.2 Custom Instrument Configurations

7.2.1 Modifying the line voltage requirements

Warning

Before removing the cover of the instrument, remove the power from the instrument by disconnecting the power cord from the power receptacle. Failure to do this could expose the user to high voltages and could result in life-threatening electrical shock.

Caution

The Model 185/186 instrument operates on 50-60 Hz power and may be configured for 110-120 or 208-240 VAC ±10% (100 or 200

VAC ±10% for Japan and South Korea). The power requirements for each instrument are marked on the rear panel. Be sure the instrument's power requirements match your power source prior to plugging in the line cord. Do not fail to connect the input ground terminal securely to an external earth ground.

If the instrument operating voltage needs to be changed, ensure the instrument is de-energized by disconnecting the power cord from the power source. Remove the instrument cover and slide the voltage selector switch on the main printed circuit board to the proper voltage. Replace the instrument cover and *indelibly mark the rear panel indications to match the new configuration.*

7.3 Additional Technical Support

If the cause of a problem cannot be located, contact an AMI Technical Support Representative at (865) 482-1056 for assistance. The AMI technical support group may also be reached by Internet e-mail at **support@americanmagnetics.com**. Additional technical information, latest software releases, etc. are available at the AMI World Wide Web site at:

http://www.americanmagnetics.com

Do not return the Model 185/186 or other liquid level system components to AMI without prior return authorization.

7.4 Return Authorization

Items to be returned to AMI for repair (warranty or otherwise) require a return authorization number to ensure your order will receive proper attention. Please call an AMI representative at (865) 482-1056 for a return authorization number before shipping any item back to the factory.

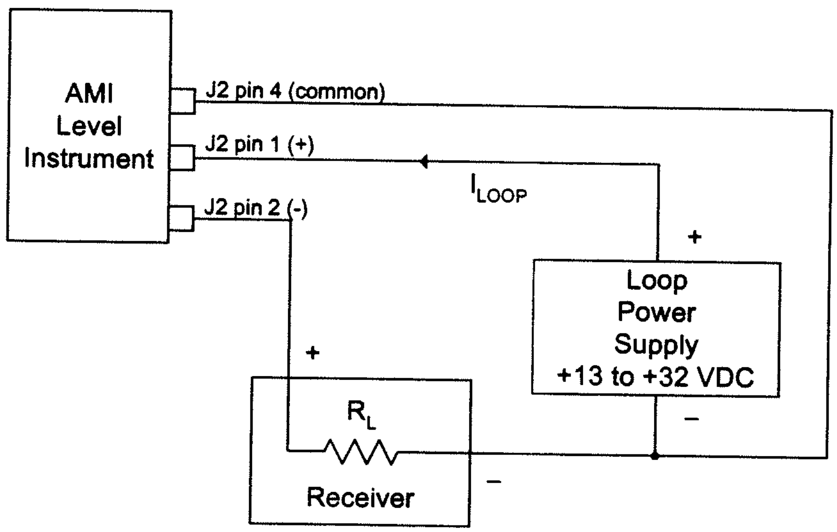
Appendix

A.1 4-20 mA current loop option

The 4-20 mA output utilizes pins 1 and 2 of connector J2. When the Model 185/186 is configured for the 4-20 mA current loop option, the 0-10 VDC analog output from connector J2 is not available. The figure below shows the wiring diagram and the voltage requirements for the power supply and receiver.

Caution

It is extremely important to observe all polarities and to not exceed +32 VDC for the loop power supply in order to prevent damage to the 4-20 mA driver circuit.

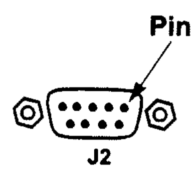


Note

For maximum immunity to external electrical and electromagnetic disturbances, all external cabling (except for the AC input, controller output, and coaxial cabling) should be shielded. The cable shield should be connected to the chassis of the instrument by connecting to the D-sub connector shell.

A.2 Auxiliary connector J2 pinout

Pin	Function
1	4-20 mA current loop power supply + (optional feature)
2	4-20 mA current loop output (optional feature)
3	0-10 VDC output (optional feature)
4	0-10 VDC common, or 4-20 mA current loop power supply common (optional feature)
5 & 6	Lo level relay contacts (dry)
7 & 8	Hi level relay contacts (dry)
9	Not used



The HI level and LO level contacts are provided for external use by the customer. When a HI or LO level condition exists, the respective contact pairs are closed. All setpoints have 1/2 mm hysteresis, therefore the respective contact pairs may "chatter" if the liquid sloshes, bubbles, etc.

The HI level and LO level contacts also provide positive indication of a power-off condition. With a power-off condition, *both* the HI level and LO level contacts will be *closed*, which is a state unique to the power-off condition.

The following table provides the specifications for the relay contacts:

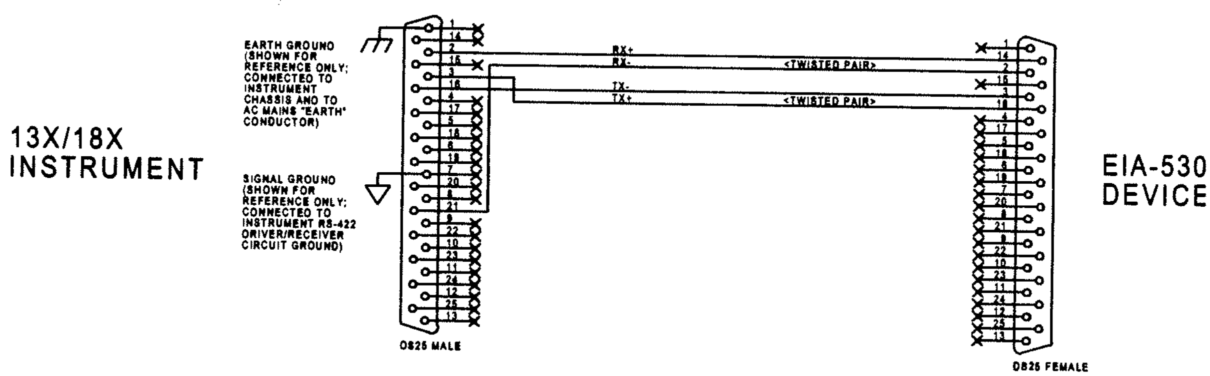
Max switching VA	10
Max switching voltage	30 VAC or 60 VDC
Max switching current	0.5 A
Max continuous current	1.5 A

A.3 RS-232 cable DB-25 to DB-9 translation

DB-25 Pin	DB-9 Pin
2	3
3	2
4	7
5	8
6	6
7	5
8	1
20	4
22	9

All other pins on the DB-25 connector are unused. This is standard PC modem cable wiring.

A.4 RS-422 Cable Wiring



13X/18X CONNECTOR	EIA-530 CONNECTOR	
RX+ (PIN 2)	TX+ (PIN 14)	TWISTED PAIR
RX- (PIN 21)	TX- (PIN 2)	
TX+ (PIN 3)	RX+ (PIN 16)	TWISTED PAIR
TX- (PIN16)	RX- (PIN 3)	

A.5 Dielectric constants for common liquids

The table below contains relative dielectric constants for several common liquids at atmospheric pressure (unless otherwise noted).

Liquid	Dielectric constant[a]
Argon (A)	1.53 @ –191°C
Carbon dioxide (CO_2)	1.60 @ 20°C, 50 atm
Hydrogen (H_2)	1.228 @ 20.4 K
Methane (CH_4)	1.70 @ –173°C
Nitrogen (N_2)	1.454 @ –203°C
Propane (C_3H_8)	1.61 @ 0°C
Oxygen (O_2)	1.507 @ –193°C

a. Reference: Weast, Robert C. Ph.D., Editor, *CRC Handbook of Chemistry and Physics 67th Edition*, CRC Press, Inc., Boca Raton, FL, 1986 (pgs. E-49 through E-53).

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