EXCELLENCE IN MAGNETICS AND CRYOGENICS

BIPOLAR POWER SUPPLY SYSTEMS

MODELS 05120PS-430-601, 05240PS-430-601, 05360PS-430-601, 05600PS-430-601 & 03300PS-430-601

INCLUDING HIGH-STABILITY OPTION

INSTALLATION, OPERATION, AND MAINTENANCE INSTRUCTIONS

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Foreword

PURPOSE AND SCOPE

This manual contains the operation and maintenance instructions for the American Magnetics, Inc. Bipolar Power Supply Systems with optional high-stability via a zero flux current sensing system. 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 Model 430 Power Supply Programmer and the Power Supply System. It provides illustrations of the front and rear panel layouts as well as documenting the performance specifications. Additional information is provided in the form of system circuit diagrams.

Installation describes how the Model 430 Power Supply Programmer 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 Model 430 Programmer is used to control a superconducting magnet. *All* Model 430 Programmer 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 Model 430 Programmer RS-232 and

Ethernet 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 Model 430 Programmer malfunctions. Information for contacting AMI Technical Support personnel is also provided.

Appendix provides additional details and/or procedures in the following areas:

- Model 430 Programmer rear panel connectors.
- Individual power supply unit specifications.
- Model 601 specifications.
- Establishing RS-232 or Ethernet communications with the Model 430.
- Model 430 firmware upgrade procedures.
- Abbreviations and acronyms used in this manual.
- Persistent switch operation (flow diagram).
- Optional Short-Sample operational mode.

APPLICABLE HARDWARE

The Model 430 Programmer 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 430 Programmer has been tested and qualified with the following power supplies or power supply systems:

AMI Model 12100PS switching power supply (12 V @ 100 A)
AMI Model 12200PS switching power supply (12 V @ 200 A)
AMI Model 7.5-140PS switching power supply (7.5 V @ 140 A)
AMI Model 10100PS switching power supply (10 V @ 100 A)
AMI Model 10200PS switching power supply (10 V @ 200 A)
AMI Model 08150PS switching power supply (1200 Watt)
AMI Model 03300PS (multiple Model 08150PS w/ Energy Absorbers; ±3 V @ 300 A)
AMI Model 05100PS (Model 08150PS w/ Energy Absorber; ±5 V @ 100 A)
AMI Model 05120PS (Model 08150PS w/ Energy Absorber; ±5 V @ 120 A)
AMI Model 05240PS (multiple Model 08150PS w/ Energy Absorbers; ±5 V @ 240 A)
AMI Model 05360PS (multiple Model 08150PS w/ Energy Absorber; ±5 V @ 360 A)
AMI Model 05400PS switching power supply w/ Energy Absorber (±5 V @ 400 A)
AMI Model 05600PS (multiple Model 08150PS w/ Energy Absorber; ±5 V @ 600 A)
AMI Model 4Q06125PS 4-quadrant switching power supply (±6 V @ ±125 A)
AMI Model 4Q06250PS 4-quadrant switching power supply (±6 V @ ±250 A)
AMI Model 4Q12125PS 4-quadrant switching power supply (±12 V @ ±125 A)
AMI Model 4Q05100PS 4-quadrant switching power supply (±5 V @ ±100 A)
Xantrex Model XFR 12-100 switching power supply (12 V @ 100 A)
Xantrex Model XFR 12-220 switching power supply (12 V @ 220 A)
Xantrex Model XHR 7.5-130 switching power supply (7.5V @ 130 A)
Hewlett-Packard 6260B linear power supply (10 V @ 100 A)
Kepco BOP 20-5M 4-quadrant linear power supply (±20 V @ ±5 A)

Kepco BOP 20-10M 4-quadrant linear power supply (±20 V @ ±10 A)
Kepco BOP 20-20M 4-quadrant linear power supply (±20 V @ ±20 A)

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 (LN2) and helium (LHe). 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 temperature extremes they are typically subjected to cause seals to fail frequently.

Treating Cold Burns

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.

Handling Cryogenic Liquids

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.

Material Safety at Cryogenic Temperatures

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 austenitic 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 IN LHE-COOLED SYSTEMS

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 (standard temperature and pressure). 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.

RISK OF EXPLOSION

Ensure cryogen container and/or magnet system vent relief valves are *kept clear*. An improperly ventilated cryostat/system may become blocked by ice with subsequent RISK OF EXPLOSION and uncontrolled release of cryogens from the system. Relief valves and rupture disks may also discharge cold gas violently without warning. Relief valves should always be pointed in a safe direction. Care must be taken not to disable pressure relief devices or otherwise create a condition where pressure buildup can occur in a magnet system or cryogen container because of the RISK OF EXPLOSION. FAILURE TO HEED THIS WARNING COULD RESULT IN INURY OR DEATH.

MAGNETIC FIELDS

The following notices should be posted to warn personnel of the dangers of strong magnetic fields produced by superconducting magnets:

i. **WARNING:** The operation of medical electronic implants, such as cardiac pacemakers, may be affected by magnetic fields, WHICH COULD CAUSE INJURY OR DEATH.

ii. **WARNING:** Medical implants, such as aneurysm clips, surgical clips or prostheses may contain ferromagnetic materials and therefore would be subject to strong forces near a magnet. THIS COULD RESULT IN INURY OR DEATH. In the vicinity of rapidly changing field (e.g. pulsed gradient fields), eddy currents may be induced in the implant resulting in heat generation.

iii. **WARNING:** Metal materials in someone's body as a result of an old injury may be affected by magnetic fields in this facility. THIS COULD RESULT IN INURY OR DEATH.

iv. **WARNING:** Large attractive forces may be exerted on equipment brought near to the magnet. The force may become large enough to move the equipment uncontrollably towards the magnet. Pieces of equipment may become projectiles and large equipment (e.g. gas bottles, power supplies) could trap bodies or limbs between the equipment and the magnet. EITHER TYPE OF OBJECT MAY CAUSE INJURY OR DEATH. The closer to the magnet you get, the larger the force is. The larger the mass of the equipment the larger the force pulling it.

v. **CAUTION:** The operation of equipment may be directly affected by the presence of large magnetic fields. Items such as watches, tape recorders, and cameras may be magnetized and irreparably damaged if exposed to magnetic fields. Information encoded magnetically on credit cards and magnetic tape including computer floppy discs, may be irreversibly corrupted. Electrical transformers may become magnetically saturated. Safety characteristics of equipment may also be affected.

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 430 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.

MINIMUM RECOMMENDED SAFETY EQUIPMENT

- First Aid kit
- Fire extinguisher rated for class C fires

- Cryogenic gloves
- Face shield
- Signs to indicate that there are potentially hazardous magnetic fields in the area and that 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).

I 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.**

Introduction

Integrated Bipolar Power Supply System Features

The AMI Model 05120PS-430-601, 05240PS-430-601, 05360PS-430-601, 05600PS-430-601, and 03300PS-430-601 Power Supply Systems allow an operator to manage a superconducting magnet system with unprecedented accuracy and ease of use.

Integral components of the system include a Model 430 Programmer with optional zero flux current sensing system (High-Stability Option), one or more Model 601 Energy Absorbers, and one or more power supplies to achieve the rated system output current. The system provides a degree of flexibility and accuracy previously unavailable in an economical commercial product.

Digitally-Controlled

The Power Supply System is controlled by the microcomputer inside the Model 430 Programmer which performs 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 430 Programmer incorporates digital signal processing (DSP) functions that provide for accurate control, low drift, and flexibility of use.

Superior Resolution and Stability

The Model 430 Programmer incorporates high-resolution converters to translate signals between the analog and digital domains. Precision instrumentation techniques and potentiometer-free designs are employed throughout the Model 430 Programmer to ensure accurate signal translation for a wide range of conditions. The magnet current is sampled at 24-bit resolution in hardware and is software-programmable to 15-digits resolution. All pause and hold functions are performed in the digital domain which provides for excellent stability and drift of the programmed magnetic field.

High-Stability Option

For greater stability and accuracy, the Model 430 Programmer can be configured with a zero-flux precision current measuring device instead of the standard resistive shunt. This option typically increases the system stability and accuracy by an order of magnitude. The power supply systems incorporating this technique are referred to as “high-stability” systems.

Intuitive Human-Interface Design

The Model 430 Programmer was designed 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 430 Programmer is intuitive to the user.

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

Flexibility

The Model 430 Programmer can be configured with the supporting hardware as a two- or four-quadrant power supply system which is able to both supply and remove electrical energy from the superconducting magnet system. The Model 430 Programmer is engineered to be compatible with most power supplies with remote analog programming capabilities.

From simple single-quadrant supplies, to more elaborate four-quadrant units, the Model 430 Power Supply Programmer is user-configurable such that the operational paradigm complies with the specific magnet system requirements.

Standard Remote Interfaces

The Model 430 Programmer provides an RS-232 serial port as well as an Ethernet port as standard features. All settings can be controlled via the remote interfaces and the front panel can be remotely locked to prevent accidental operation. The Model 430 Programmer also provides remote trigger functions for data collection and/or logging during operation.

Programmable Safety Features

The Power Supply System is designed to be operated from the front panel of the Model 430 Programmer 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 Model 430 Programmer will not accept the parameter and will alert the operator that a value was rejected because it was outside the user-defined limits.

In addition, each setup parameter can be individually selected for locking. A user-defined password is required to lock or unlock settings. This allows an administrator to set and password protect any critical parameters that should not be changed by the operator. Then the administrator can be confident that an operator will not subsequently change any of these critical parameters, and yet will be free to change any non-critical (unlocked) parameters.

CONDITION-BASED MAGNET AUTO-RAMPDOWN

The Model 430 Programmer can be connected to an AMI Model 1700 Liquid Level Instrument, with the LHe measurement option, to allow automatic rampdown of the magnet (even in persistent mode) should the liquid helium (LHe) level drop to a preset level. This feature ensures the magnet will be protected and not experience a quench should the LHe level reach an unsafe level for magnet operation. A single cable is required to use this feature and is covered in more detail on page 198 of the *Appendix*. Contact AMI for more information.

In addition to low LHe level, inputs to the Model 430 Programmer can be used with other instrumentation as well. Other uses include faults from a cryocooler, temperature measurement limit, etc.

BIPOLAR SYSTEMS GENERAL DESCRIPTION

AMI's bipolar power supply systems rely upon unipolar power supplies and the AMI Model 601 Energy Absorber to achieve two-quadrant operation (bipolar voltage only). The unipolar power supplies used in the systems can be configured to provide various voltage and current output within the output *power limits* of the supply. Therefore, the Model 08150PS power supply (0-8 VDC, 0-150 A) can be alternately configured for 0-10 V output at a maximum current of 120 A. This a common configuration for superconducting magnet applications as it provides up to a +5 VDC charge rate (minus lead losses; power leads resistance is typically around 10 milliohms).

As a unipolar power supply, the Model 08150PS can only source[1] (not sink) power. However, when the power supply is used in conjunction with the AMI Model 601 Energy Absorber, the result is the bipolar Model 05120PS-430-601 integrated power supply system that is ideal for

1. The power supply is operating as a source if the current direction and voltage polarity are the same (e.g. the situation that would exist when supplying a resistive load). If the voltage polarity and current direction are opposite, the supply is operating as a sink.

driving inductive loads such as large magnets or motors. The Model 601 Energy Absorber provides a -5 VDC discharge capacity.[2]

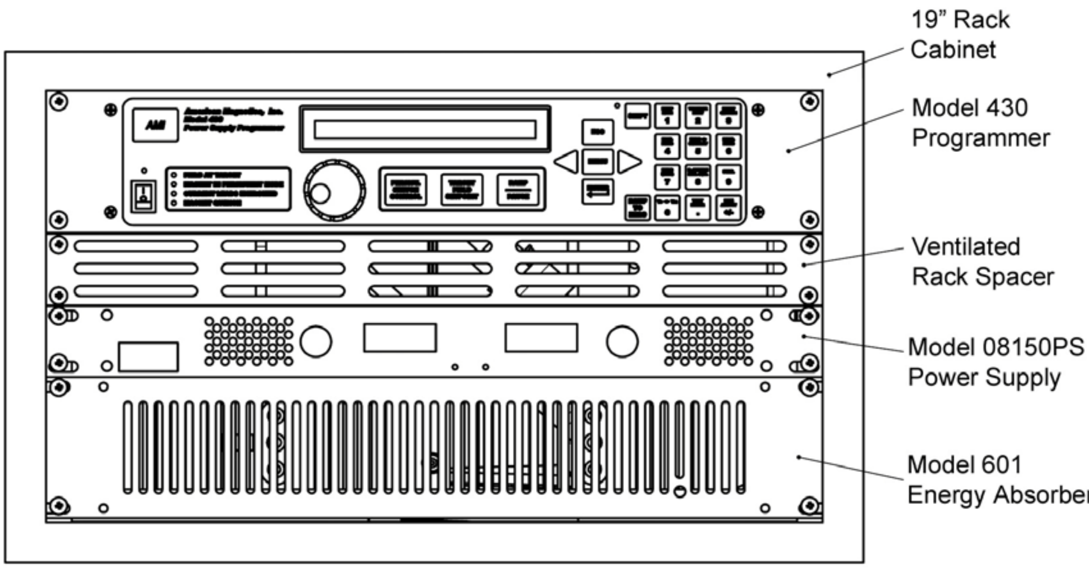
The power supply is controlled by a 0-10 VDC remote analog signal supplied by the Model 430 Programmer and applied to the power supply analog input. Programming and control of the current loop (composed of the magnet, power supply, and Model 430 Programmer shunt or optional zero flux current measurement device), is provided by an internal Model 430, ramp-generated current reference with parameters as set by the user. The Model 430 continuously compares the measured current with its internal current reference to provide precise closed-loop control of the actual current.

The power supplies are operated in voltage-commands-voltage[3] programming mode, with the Model 430 Programmer output scaled to operate the power supply over its available voltage output range. The Model 430 Programmer signal will continually adjust the power supply output voltage to automatically regulate the loop current; precise linear current control will result as long as the system voltage and current demands do not exceed the power supply rating or load limiting parameters.

2. This -5 VDC discharge or “reverse-bias” is continually present when operating the bipolar power supply systems at greater than zero current. The primary energy discharge method is by heat dissipation of the converted electrical energy.
3. Voltage reference controlling voltage output.

MODEL 05120PS-430-601 POWER SUPPLY SYSTEM

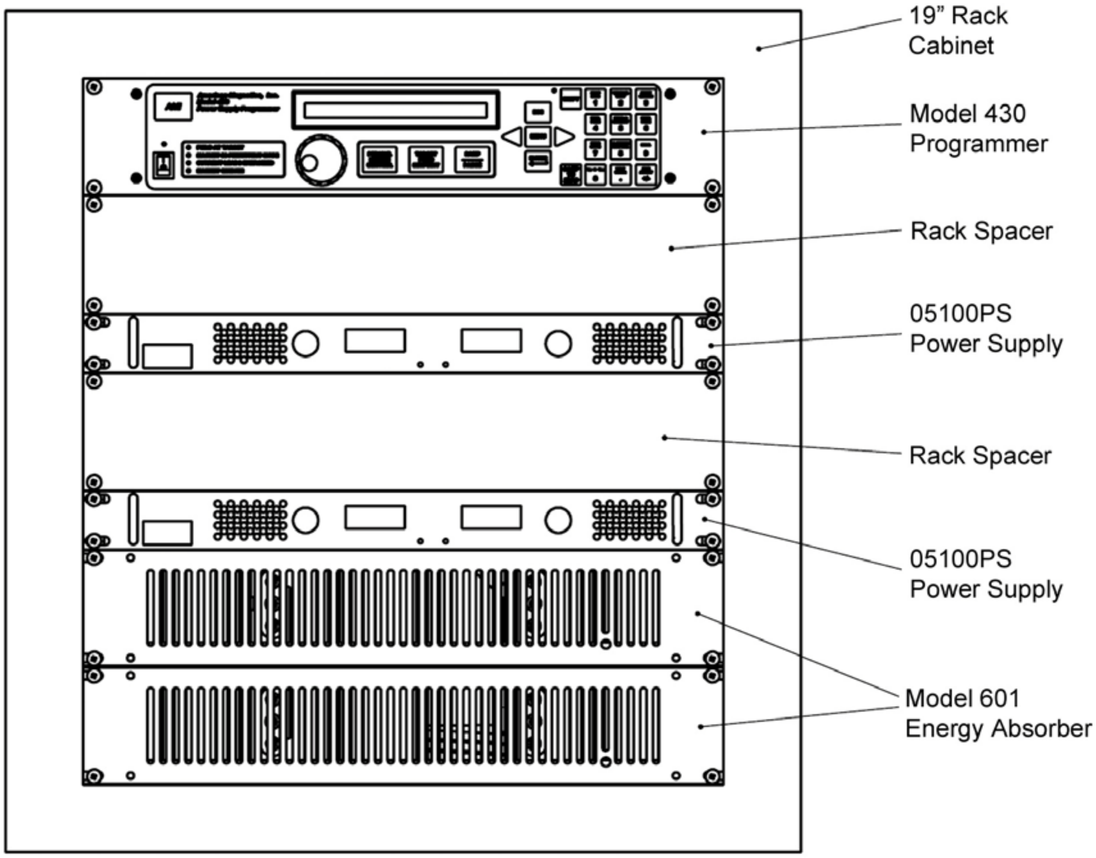
The system consists of a Model 430 Programmer, a 08150PS power supply configured for 0-10 VDC and 0-120 A output, and a Model 601 Energy Absorber as illustrated below. The system provides ±5 VDC to the load at up to 120 A maximum current.



Typical Model 05120PS-430-601 System Rack Layout

MODEL 05240PS-430-601 POWER SUPPLY SYSTEM

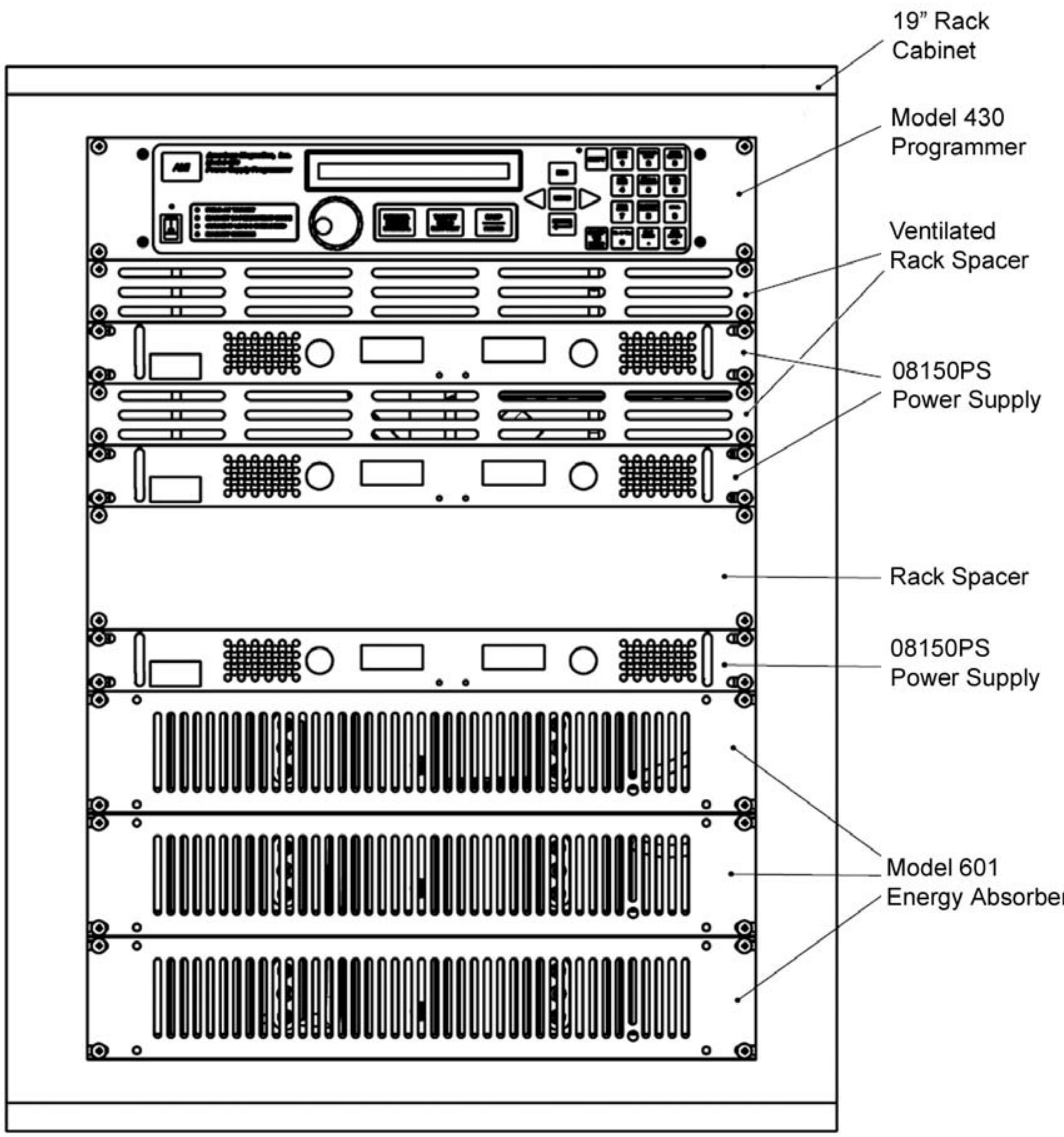
The system consists of a Model 430 Programmer, two 08150PS power supplies configured for 0-10 VDC and 0-120 A output, and two Model 601 Energy Absorbers as illustrated below. The system provides ±5 VDC to the load at up to 240 A maximum current.



Typical Model 05240PS-430-601 System Rack Layout

MODEL 05360PS-430-601 POWER SUPPLY SYSTEM

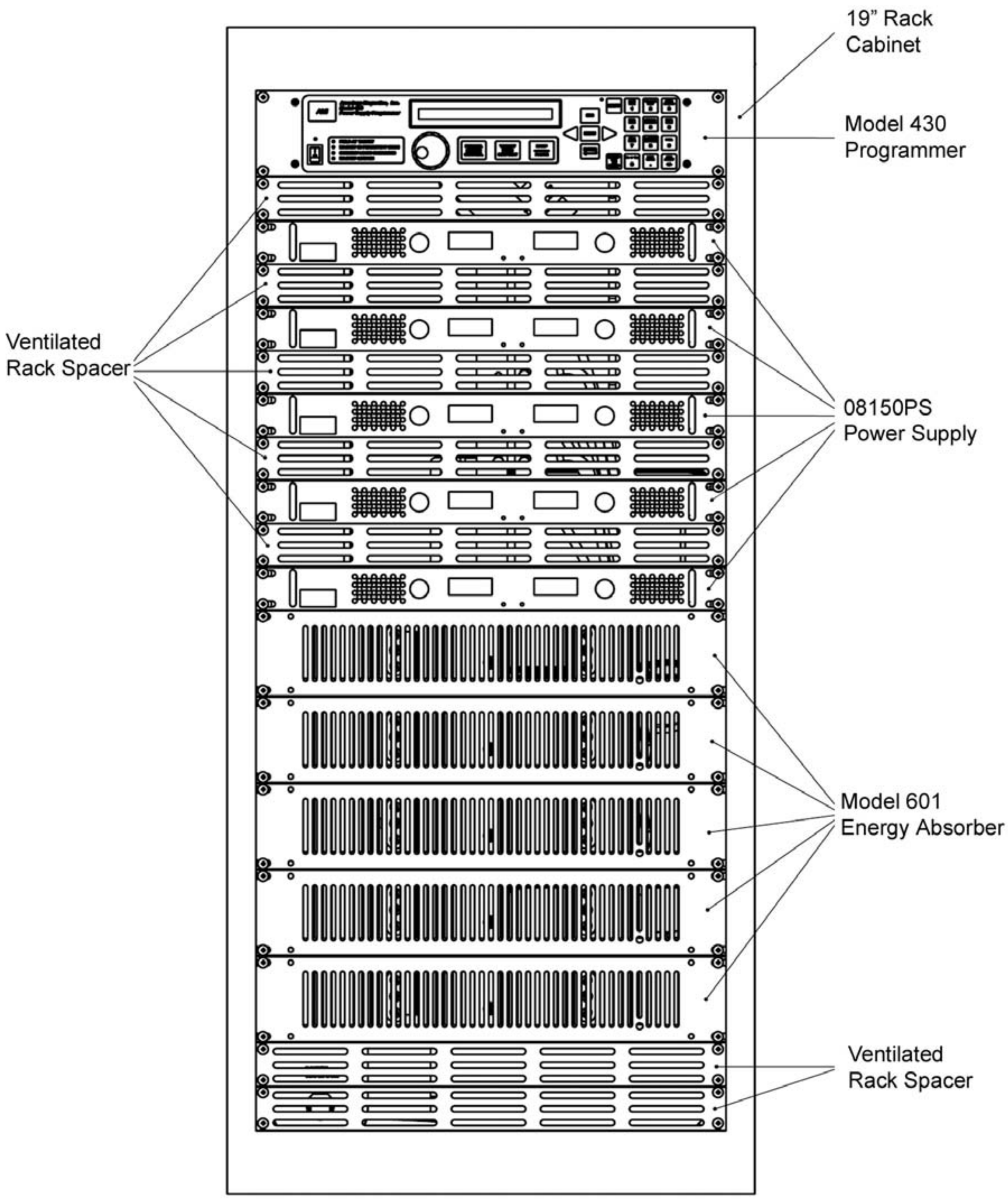
The system consists of a Model 430 Programmer, three 08150PS power supplies configured for 0-10 VDC and 0-120 A output, and three Model 601 Energy Absorbers as illustrated below. The system provides ±5 VDC to the load at up to 360 A maximum current.



Typical 05360PS-430-601 System Rack Layout

MODEL 05600PS-430-601 POWER SUPPLY SYSTEM

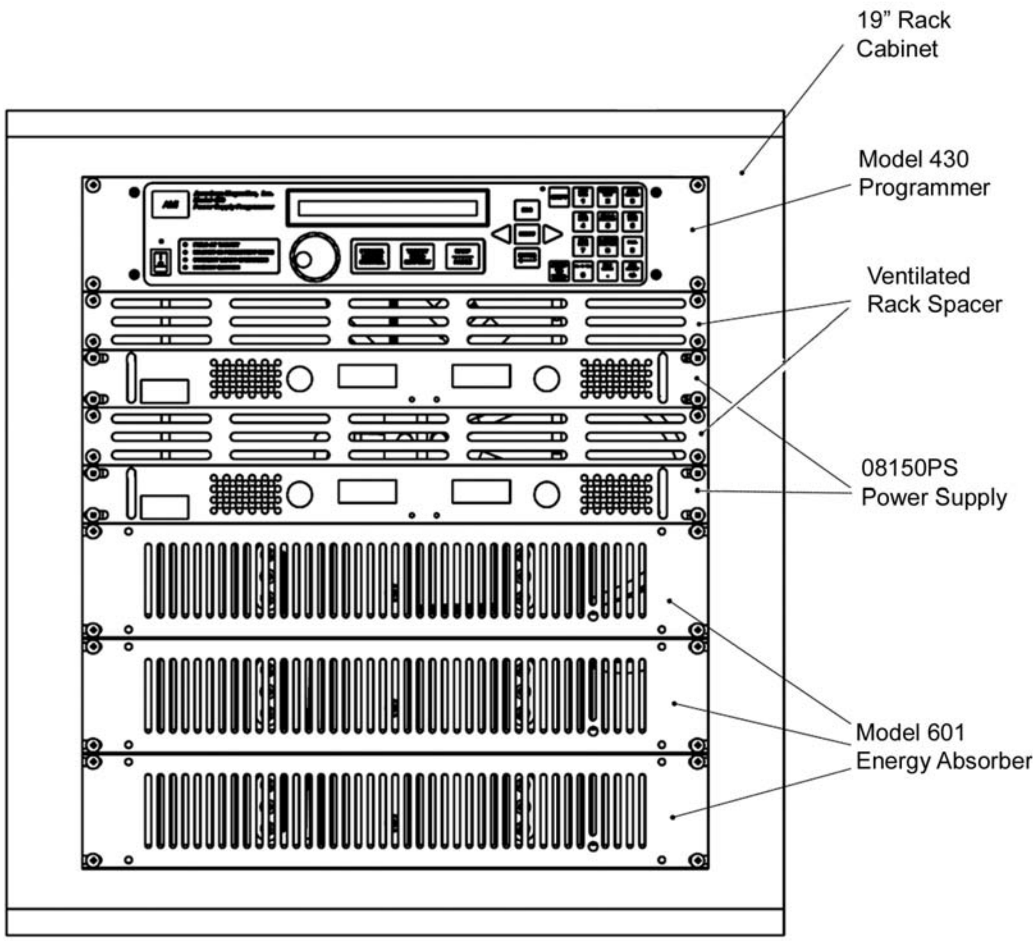
The system consists of a Model 430 Programmer, five 08150PS power supplies configured for 0-10 VDC and 0-120 A output, and five Model 601 Energy Absorbers as illustrated below. The system provides ±5 VDC to the load at up to 600 A maximum current.



Typical 05600PS-430-601 System Rack Layout

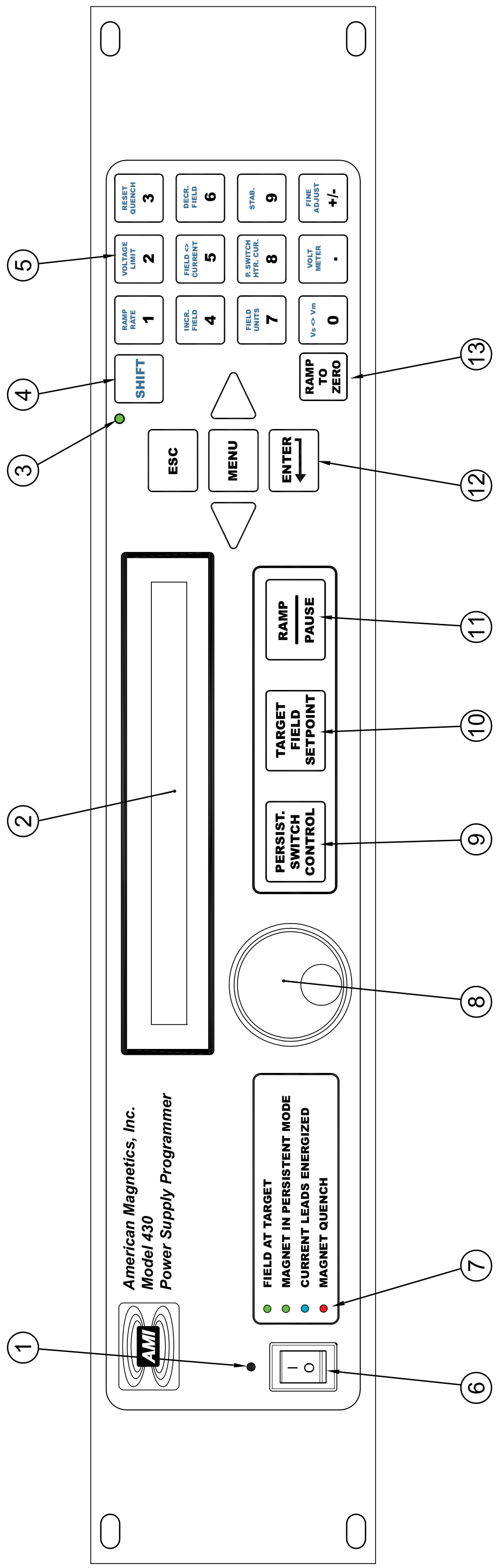
MODEL 03300PS-430-601 POWER SUPPLY SYSTEM

The system consists of a Model 430 Programmer, two 08150PS power supplies configured for 0-8 VDC and 0-150 A output, and two Model 601 Energy Absorbers as illustrated below. The system provides -5 VDC to +3 VDC to the load at up to 300 A maximum current.



Typical Model 03300PS-430-601 System Rack Layout

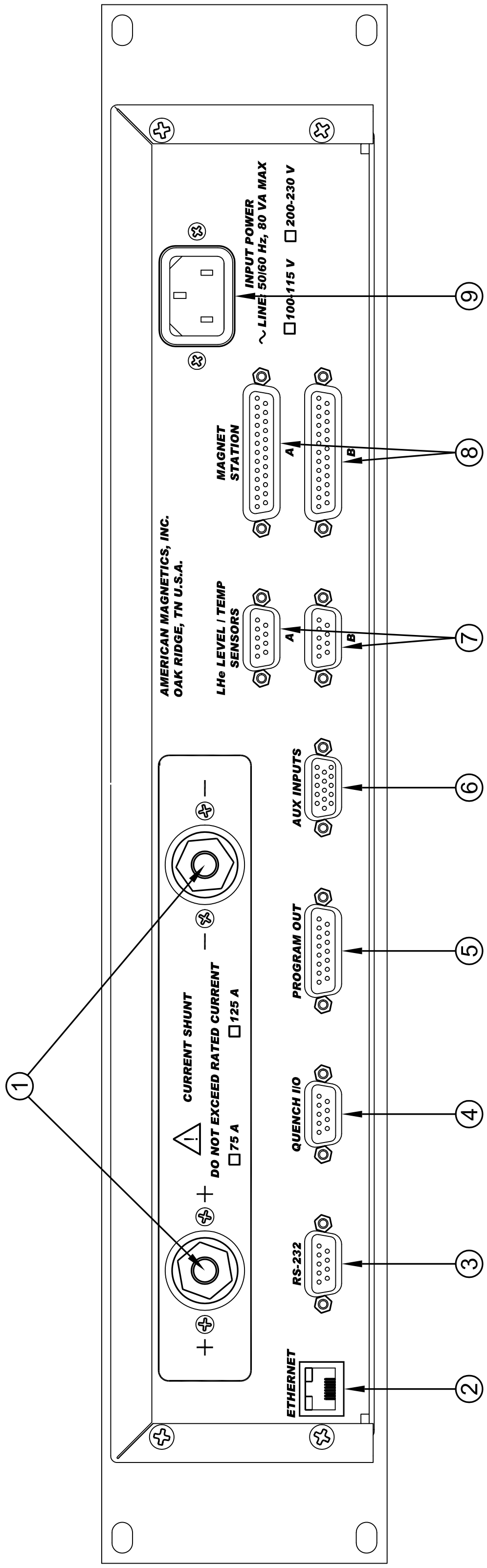
MODEL 430 FRONT PANEL LAYOUT



1	Power Indicator LED	8	Fine Adjust Knob
2	280 x 16 Dot Graphic VF Display	9	Persistent Switch Heater Control Key
3	Shift Indicator LED	10	Target Field Setpoint Key
4	Shift Key	11	Ramp/Pause Switch
5	4 Row x 3 Column Keypad	12	Menu Navigation and Data Entry Keys
6	Power Switch	13	Ramp to Zero Key
7	Magnet Status Indicator LEDs		

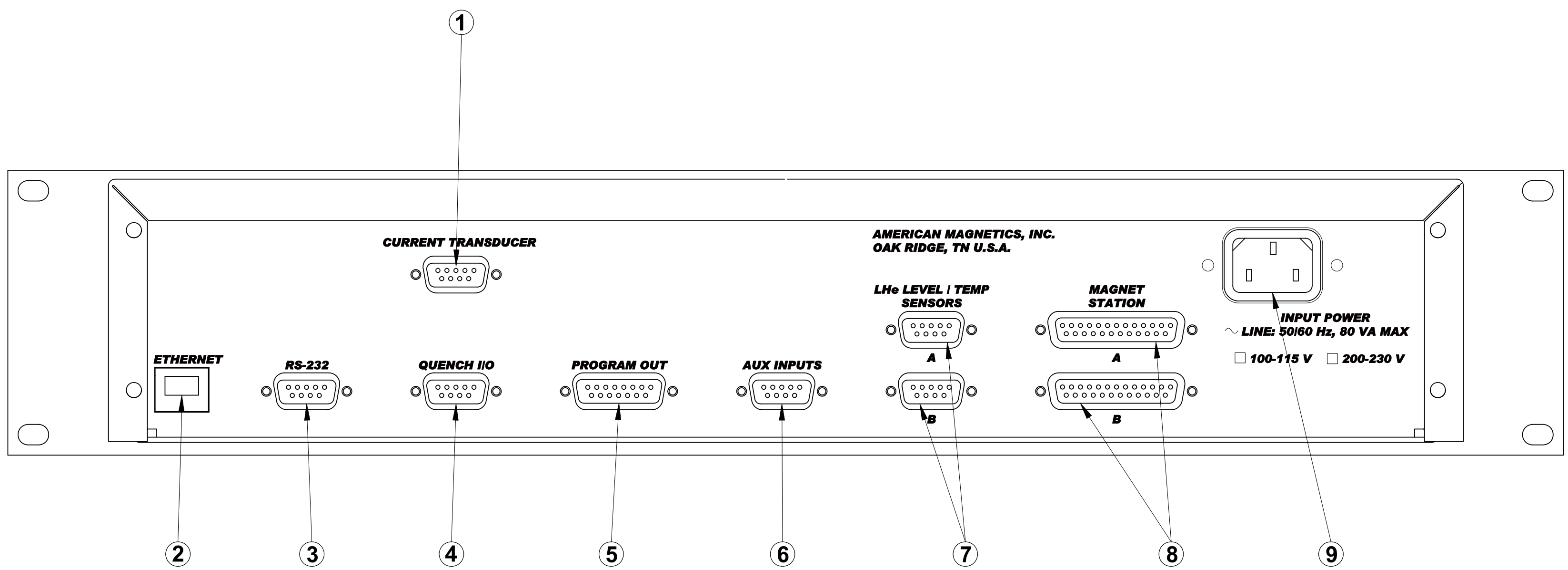
Model 430 Front Panel Description

MODEL 430 REAR PANEL LAYOUT



1	Current Shunt Terminals	6	Aux Inputs 15-pin Female HD D-sub Connector
2	Ethernet RJ-45 Connector	7	Dual Auxiliary LHe Level/Temp 9-pin Male D-sub Connectors
3	RS-232 9-pin Male D-sub Connector	8	Dual Magnet Station 25-pin Female D-sub Connectors
4	Quench I/O 15-pin Male D-sub Connector	9	Input Power IEC 60320 C14 Male Connector
5	Program Out 15-pin Male D-sub Connector		

Model 430 Resistive Shunt Version Rear Panel Description

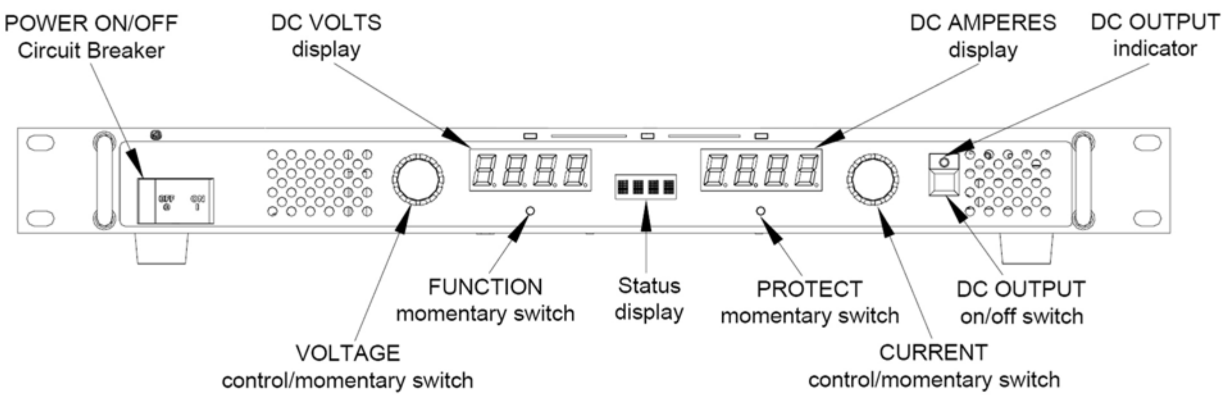


1 Current Transducer 9-pin Female D-sub Connector	**6** Aux Inputs 15-pin Female HD D-sub Connector
2 Ethernet RJ-45 Connector	**7** Dual Auxiliary LHe Level/Temp 9-pin Male D-sub Connectors
3 RS-232 9-pin Male D-sub Connector	**8** Dual Magnet Station 25-pin Female D-sub Connectors
4 Quench I/O 15-pin Male D-sub Connector	**9** Input Power IEC 60320 C14 Male Connector
5 Program Out 15-pin Male D-sub Connector	

Model 430 Zero Flux Version Rear Panel Description

POWER SUPPLY UNIT FRONT PANEL LAYOUT

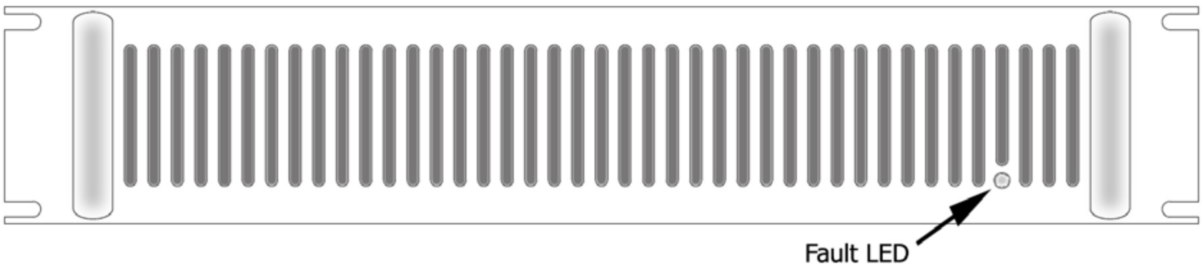
The Bipolar Power Supply System individual power supply front panels contain the input ON/OFF circuit breakers and the OUTPUT indicator. The remaining front panel controls *are not used* in the Bipolar Power Supply System configuration because the system output is controlled by the Model 430 Programmer. Refer to figure and table below for the panel controls and indicators.



Power Supply Front Panel Controls and Indicators

Control or Indicator	Function
POWER ON/OFF Circuit Breaker	Turns the power supply on or off. Circuit breaker provides input overload protection.
DC VOLTS display	Four-digit LED display that shows output voltage.
Status 4 character display	Displays active function or blinks for error messages. Normally blank.
DC AMPERES display	Four-digit LED display that shows output current.
DC OUTPUT indicator	Green LED lights when DC output is enabled. LED is off when output is disabled.

MODEL 601 ENERGY ABSORBER FRONT PANEL LAYOUT



Model 601 Front Panel Layout

The Fault LED is the only indicator on the Model 601 front panel. If the Fault LED is *not* energized, the Model 601 is operating correctly. If the Fault LED is energized, then one or more of the internal energy absorbing elements has malfunctioned or power has been lost to the rear-panel power connector. An audible alarm will also sound when the Fault LED is energized.

CAUTION **If the system is in operation when an energy absorber fault occurs, a safe magnet system state (typically zero current or a cooled persistent switch in a connected magnet) should immediately be attained. Do not continue to operate the unit, and refer to the "Troubleshooting Hints" on page 182 for further instructions.**

BIPOLAR SYSTEM SPECIFICATIONS

Shunt-based (w/ optional High-Stability) Bipolar Power Supply System Specifications

Magnet Current Control	**05120PS-430**	**05240PS-430**
Range:	0 to +120 A	0 to +240 A
Programming Accuracy:	50 mA	100 mA
Programming Accuracy w/ High-Stability Option:	6.3 mA	12.5 mA
Stability (w/ internal shunt):	2.5 mA after 20 min. at desired current	5.0 mA after 20 min. at desired current
Stability w/ High-Stability Option:	1.25 mA after 10 min. at desired current	2.5 mA after 10 min. at desired current
Minimum Ramp Rate (w/ internal shunt):	75 µA/min	150 µA/min
Minimum Ramp Rate w/ High-Stability Option:	7.5 µA/min	15 µA/min
Maximum Ramp Rate:	12.5 A/sec	25.0 A/sec
Output Voltage		
Range:	–5 to +5 VDC	
Measurement Resolution:	10 mV	
Load Inductance		
Range:	0.05 to 200 H	
Primary Power Requirements		
Range:	100 - 115 or 200 - 230 VAC ±10% 50 / 60 Hz, 1800 VA	100 - 115 or 200 - 230 VAC ±10% 50 / 60 Hz, 3000 VA
Physical		
Dimensions[a]:	12.5” H x 21”W x 24.5” D (318 mm H x 533 mm W x 622 mm D)	19.5” H x 21”W x 24.5” D (495 mm H x 533 mm W x 622 mm D)
Approximate Weight:	70 lbm (30 kg)	160 lbm (75 kg)
Additional High-Stability Option Weight:	10 lbm (4.5 kg)	
Terminal Torque Limit:	48 lbf-in (5.4 N-m)	
Environmental Limits		
Ambient Temperature:	0 °C to 40 °C (32 °F to 104 °F)	
Relative Humidity:	0 to 95%; non-condensing	

a. H = height; W = width; D = depth

High-Current (High-Stability Option required) Bipolar Power Supply System Specifications

Magnet Current Control	**05360PS-430**	**05600PS-430**	**03300PS-430**
Range:	0 to +360 A	0 to +600 A	0 to +300 A
Programming Accuracy:	18 mA	30 mA	15 mA
Stability:	3.6 mA after 10 min. at desired current	6 mA after 10 min. at desired current	3 mA after 10 min. at desired current
Minimum Ramp Rate:	21.6 µA/min	36 µA/min	18 µA/min
Maximum Ramp Rate:	36.0 A/sec	60 A/sec	30 A/sec
Output Voltage			
Range:	–5 to +5 VDC		–5 to +3VDC
Measurement Resolution:	10 mV		
Load Inductance			
Range:	1 to 1000 H		
Primary Power Requirements			
Range:	100 - 115 or 200 - 230 VAC ±10% 50 / 60 Hz, 4500 VA	100 - 115 or 200 - 230 VAC ±10% 50 / 60 Hz, 7000 VA	100 - 115 or 200 - 230 VAC ±10% 50 / 60 Hz, 3500 VA
Physical			
Dimensions[a]:	30.0” H x 21”W x 24.5” D (762 mm H x 533 mm W x 622 mm D)	47.2” H x 21.33”W x 24.5” D (1200 mm H x 542 mm W x 622 mm D)	25” H x 23.6”W x 23.6” D (636 mm H x 600 mm W x 600 mm D)
Approximate Weight:	215 lbm (100 kg)	330 lbm (150 kg)	160 lbm (75 kg)
Terminal Torque Limit:	48 lbf-in (5.4 N-m)		
Environmental Limits			
Ambient Temperature:	0 °C to 40 °C (32 °F to 104 °F)		
Relative Humidity:	0 to 95%; non-condensing		

a. H = height; W = width; D = depth

MODEL 430 SPECIFICATIONS @ 25 °C

Magnet Current Control Parameters	Standard Model 430 Factory Configurations: Programmable Limits								
I_{max}:	±5 A	±10 A	+100 A	+120 A	±125 A	+240 A	±250 A	+300 A	+600 A
Measurement Resolution (μA):	0.625	1.25	12.5	15.6	15.6	31.2	31.2	37.4	75.0
Accuracy (% of I_{max}):	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.005	0.005
Minimum Ramp Rate (μA/min)[a]:	3	6	60	75	75	150	150	18	36
Maximum Ramp Rate (A/sec):	0.5	1	10	12.5	12.5	25	25	30	60

a. Minimum ramp rate is 1/10th of the listed value with the high-stability option installed for systems up to ±250 A. Systems with higher maximum current capacity include the high-stability option as standard.

Additional Model 430 Programmer Specifications

Magnet Current Control

Temperature Coefficient:	0.01% of I_{max} / °C
Stability (w/ internal shunt):	With standard internal shunt, better than 0.002% of I_{max} after 20 minutes at desired current
w/ High-Stability Option:	With High-Stability Option (zero flux current transducer), better than 0.001% of I_{max} after 10 minutes at desired current
Noise Floor Relative to I_{max}:	–127 dB w/ internal shunt, –138 dB with High-Stability Option
Target Setpoint Entry Precision:	15 digits[a]
Ramp Rate Entry Precision:	15 digits[a]
Nominal Load Inductance Range:	0.05 to 200 H (extended range of 0.01 to 1000 H available)

Program Out Voltage

Programmable Limits:	–10 to +10 VDC
Accuracy:	3 mV (0.03% of V_{max})
Temperature Coefficient:	0.2 mV / °C (0.002% of V_{max} / °C)
Resolution:	0.3 mV
Stability:	Better than 10 mV p-p when paused or holding (with 0.05 to 200 H load)

Magnet Voltage Measurement

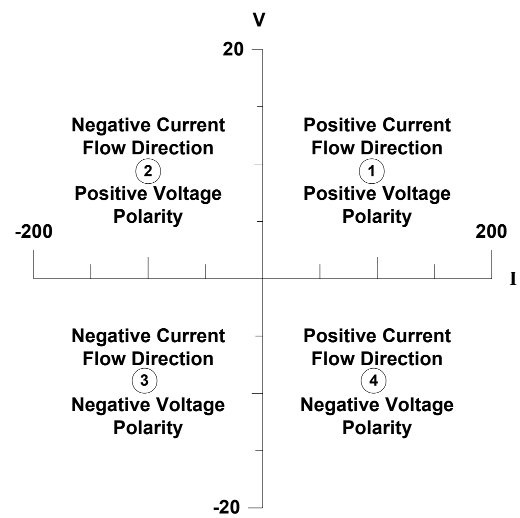
Maximum Limits:	–20 to +20 VDC
Accuracy:	20 mV (0.1% of V_{max} / °C)
Temperature Coefficient:	1.5 mV / °C (0.0075% of V_{max} / °C)
Resolution:	10 mV

Persistent Switch Heater Output	
Programmable Limits:	0.0 to 100 mA DC
Accuracy:	0.2 mA
Temperature Coefficient:	0.01 mA / °C
Maximum Compliance:	14 V
Resolution:	0.03 mA
Rampdown and Quench Inputs	
Open Circuit Voltage:	5 VDC ±5%
Input Resistance:	10 kΩ ±1%
Quench Dry Contact Output	
Maximum Switching Voltage:	60 VDC
Maximum Switching VA:	10 VA
Maximum Switching Current:	500 mA, unless limited by VA rating
Galvanic Isolation:	125 VDC
Power Requirements	
Primary:	100-115 VAC or 200-230 VAC ±10% 50 / 60 Hz, 100 VA max., 30 W max.
Real-time Clock Backup Battery:	3 V CR2032 Lithium coin 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:	8.5 lbm (3.9 kg)
Terminal Torque Limit:	48 in-lb (5.4 N-m)
Environmental	
Ambient Temperature:	Operating: 0 °C to 50 °C (32 °F to 122 °F) Nonoperating: –20 °C to 70 °C (–4 °F to 158 °F)
Relative Humidity:	0 to 95%; non-condensing
Standards	
EMI/EMC Standards:	EN 61000-4-2 EN 61000-4-3 EN 61000-4-4 EN 61000-4-5 EN 61000-4-6 EN 61000-4-8 EN 61000-4-11 EN 61000-3-2 EN 61000-3-3 EN 55011
Safety Standard:	EN61010-1
Installation Category:	Pollution Degree 2, Overvoltage Category II as defined by IEC664

a. Resolution of the IEEE 754 double-precision floating point type consisting of a 52-bit fraction and 11-bit exponent. Actual *controlled* accuracy and resolution depend upon the specific load configuration and hardware performance limits.

OPERATING CHARACTERISTICS

The Model 430 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 are categorized by one of three forms: *single-quadrant*, *dual-quadrant*, and *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 the figure below:



The Four Regions, or Quadrants, of System Operation

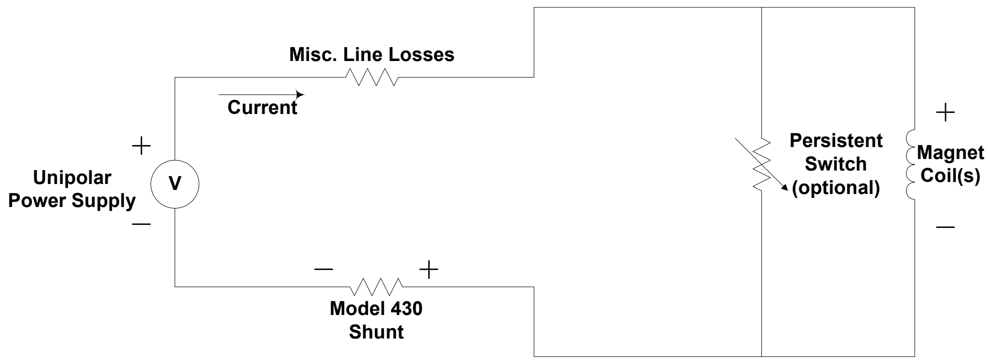
NOTE **The resistive current measurement shunt in the following system diagrams, which is internal to the Model 430 chassis, can be optionally replaced with an external high-stability, precision zero flux current measurement device for additional cost. This is termed the “High-Stability” option for AMI power supply systems.**

SINGLE-QUADRANT OPERATION

The simplest form of a Programmer-Power Supply system is the single-quadrant system as illustrated in the figure at the top of the following page. The system is composed of a Model 430 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. The electrical energy can be stored as magnetic energy as fast as the magnet and power supply voltage will allow.

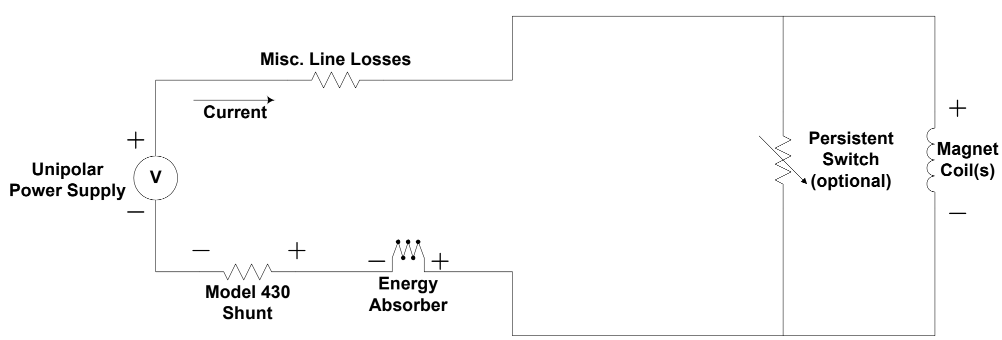
In order to reduce the magnetic field, the magnetic energy is converted to electrical energy and then to thermal energy in the resistive elements of the system. The magnitude of the resistive elements determines how fast the magnetic field can be collapsed and is typically very slow in the single-quadrant system. AMI does not recommend single-quadrant operation with large inductive loads due to the extremely long discharge times involved.



Single-Quadrant System with Resistive Shunt

DUAL-QUADRANT OPERATION

In the Bipolar Power Supply System, an energy absorber is added in series with the unipolar supply; this allows stored magnetic energy to be converted to thermal energy, thereby allowing much faster magnetic field reduction. This corresponds to operation in quadrants 1 and 4, referring to the figure on page 19.



Dual-Quadrant (Bipolar) System with Resistive Shunt

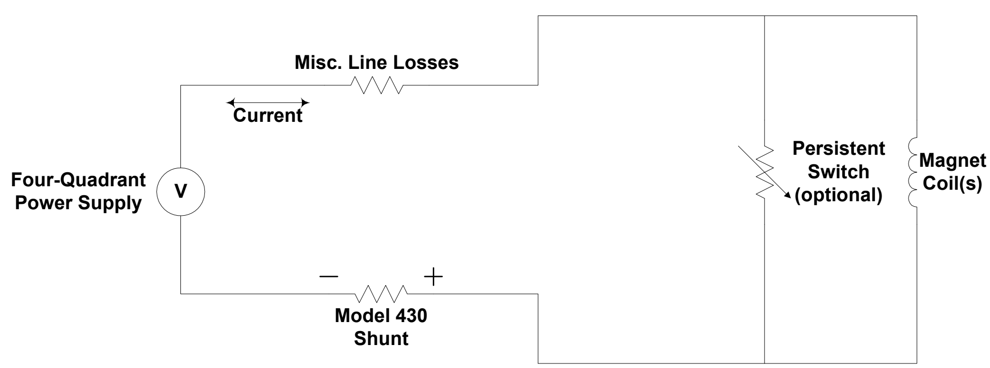
The disadvantage to this type of system is that energy is being dissipated in the energy absorbing element whenever current is flowing.

This loss is sometimes a significant portion of the power required to operate the system. It also does not provide for field polarity reversal.

FOUR-QUADRANT OPERATION

The Four-Quadrant Magnet Power Supply System illustrated in the figure below offers the most control of all the modes of operation. Efficiency is increased and reversible magnetic field profiles are attainable without discontinuities in the current. The magnetic energy sink returns a significant portion of the power to the AC line instead of dissipating it as heat.

Disadvantages of the four-quadrant system include somewhat increased cost of the power supply over unipolar power supplies or bipolar power supply systems, and added complexity in protecting the power supply in the event of AC power loss or magnet quenching. Nonetheless, modern four-quadrant power supplies which include integral output protection against AC power loss and magnet quenching are available at reasonable prices.



Four-Quadrant System with Resistive Shunt

Installation

WARNING	**Before energizing the equipment, 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 becomes less than sufficient to carry the rated current of the power circuit, the equipment should be disconnected from power, labeled as unsafe, and removed from place of operation.**

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

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

WARNING	**If used in a manner not specified in this manual, the protection provided by the design, manufacture and documentation of the power supply system may be impaired.**

INSPECTING AND UNPACKING

Carefully remove the equipment, interconnecting cabling, and documentation CD (and/or printed material) from the shipping carton, and remove all packaging material.

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

POWER SUPPLY SYSTEM MOUNTING

If the power supply system is to be used on a table top, place all components on a flat, secure surface capable of handling the weight. Allow adequate room for ventilation ports to operate.

POWER REQUIREMENTS

WARNING **The power requirement for each system component is marked on the rear panel of the unit adjacent to the power entry connectors. Be sure the power supply system is configured for the proper facility power prior to plugging in the line cords. Do not fail to connect the input ground terminal securely to an external earth ground.**

CAUTION **If the system includes the High-Stability Option, operating the system without power applied to the current transducer (CT) can result in loss of control, and may damage the CT.**

NOTE **AMI recommends energizing the Model 430 Programmer from the same power source as the power supply to be controlled. Since both the Programmer and the power supply are floating, if the ground potentials of the Programmer 115 VAC outlet and the Power Supply 230 VAC outlet different, an AC ground loop can form which can cause control anomalies. Refer to following section if the line voltage needs to be changed to 230 VAC.**

Ensure the front panel power switches are in the O (OFF) position. Verify that the Model 430 Programmer and power supply component(s) are configured for the proper operating voltage by referring to the label adjacent to the power entry connector on the equipment rear panels. If the operating voltage is correct, plug the line cords into the power entry connectors, and then into the appropriate facility power receptacles.

CHANGING THE MODEL 430 PROGRAMMER OPERATING VOLTAGE

WARNING **The following procedure is to be performed only when the Model 430 Programmer 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.**

NOTE **The voltage selector switch is labeled “115” for nominal line voltages from 100 to 115 VAC. The switch is labeled “230” for nominal line voltages of 200 to 230 VAC.**

If the Model 430 Programmer operating voltage must be changed, ensure the instrument is de-energized by disconnecting the power cord from the power source. Remove the Model 430 Programmer cover by removing the four screws on both sides of the cover and the four screws from the corners of the cover on the back panel; slide the voltage selector switch on the main printed circuit board to the proper voltage. Replace the Model 430 Programmer cover.

COLLECTING NECESSARY INFORMATION

In order to properly configure the Model 430 Programmer, specific system information is required. Such parameters as the magnet electrical properties, type of power supply, persistent switch heating current requirements, and voltage and current constraints of the magnet are entered into the Model 430 Programmer once and nonvolatile 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 on page 105.

If the Model 430 Programmer was purchased as part of a magnet system, essential data will have already been entered at the AMI factory and a configuration sheet will have been provided detailing the settings.

SYSTEM INTERCONNECTS

If the Model 430 Programmer was purchased as part of a magnet system, all applicable system components and wiring harnesses will have been shipped with the system.

Multiple power supplies should be connected to the same AC input power source. The protection is configured so that a fault will shut down all the interconnected power supplies.

For maximum immunity to AC line noise, ensure that the chassis of the Model 430 Programmer 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.

The system diagrams that follow will assist in system equipment connections.

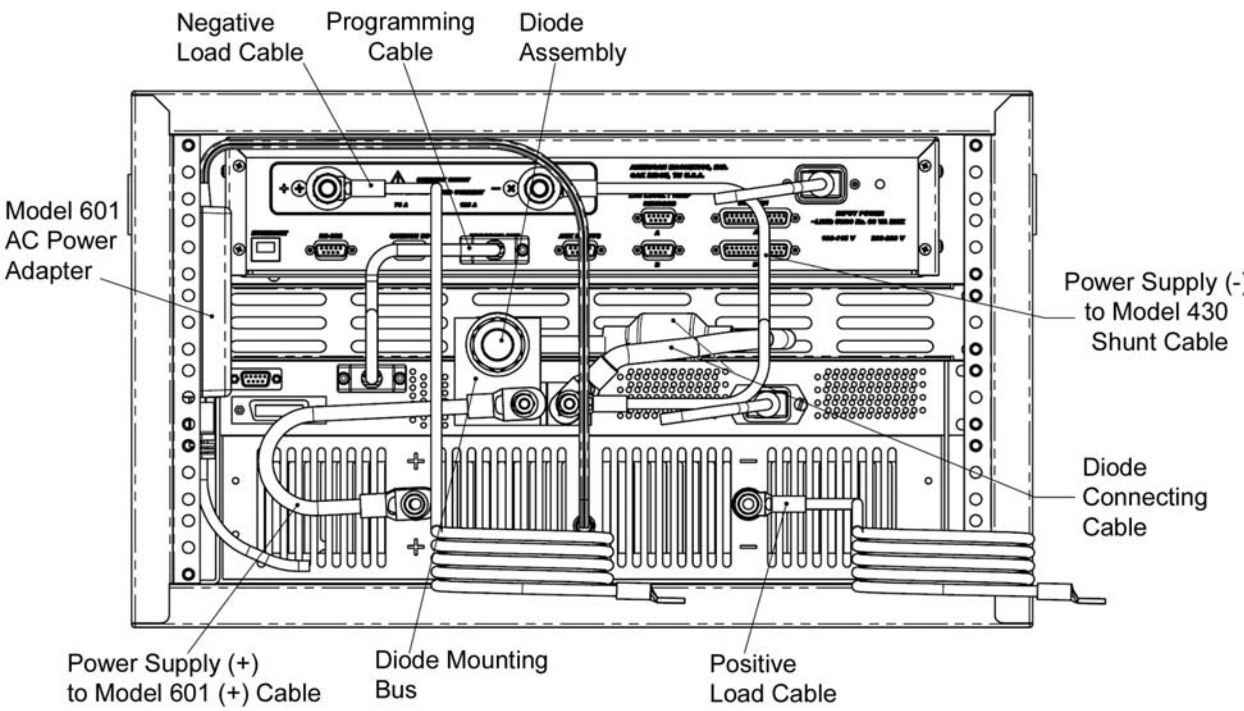
CAUTION **The wiring between the power supply and the magnet current leads must be of sufficient size to carry the full rated current of the power supply. Typically, for short runs (less than 25 ft, or 7.6 m), 2 AWG wire is sufficient for 125 A current, and 2/0 AWG wire is best for 250 A current. Consult with an AMI Technical Support Representative for higher current applications.**

Note that an AMI Model 1700 Liquid Level Instrument (with the LHe measurement option) is shown as a possible component of each integrated system. The main instrumentation cable connecting the magnet support stand to one of the Model 430 Programmer MAGNET STATION connectors 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. Refer to the *Appendix* for pin-outs of these and other connectors.

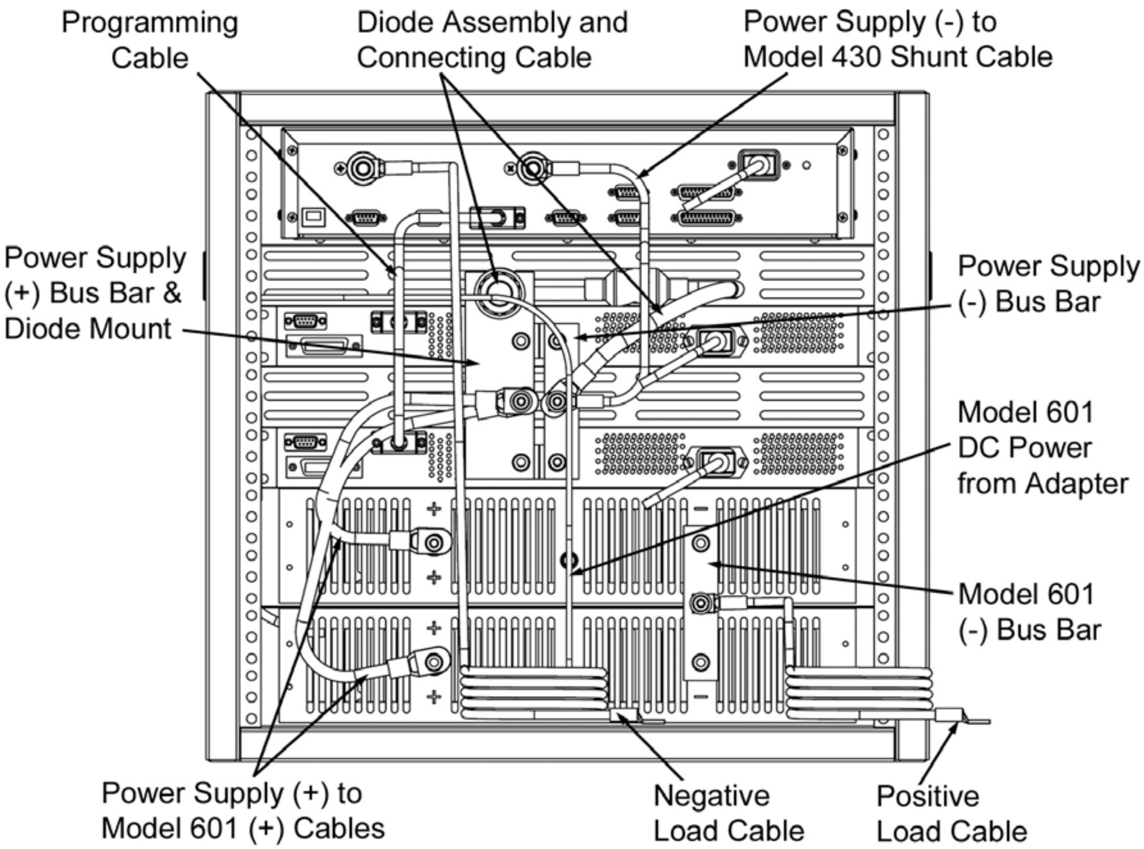
SHUNT-BASED BIPOLAR POWER SUPPLY SYSTEM

This section illustrates the interconnections for the 05120PS-430-601 (page 29) and 05240PS-430-601 (page 30) power supply systems. Both systems may be optionally fitted with the High-Stability Option with zero-flux current transducer, although that optional configuration is *not* illustrated herein.

For the bipolar (dual-quadrant) mode with shunt method of current sensing, the magnet power supply system consists of the Model 430 Programmer, one or two unipolar 08150PS power supplies (each configured for +10 VDC/120 A output), and one or two Model 601 Energy Absorbers with associated interconnection cabling and buswork.



Typical Model 05120PS-430-601 System Rack Interconnections

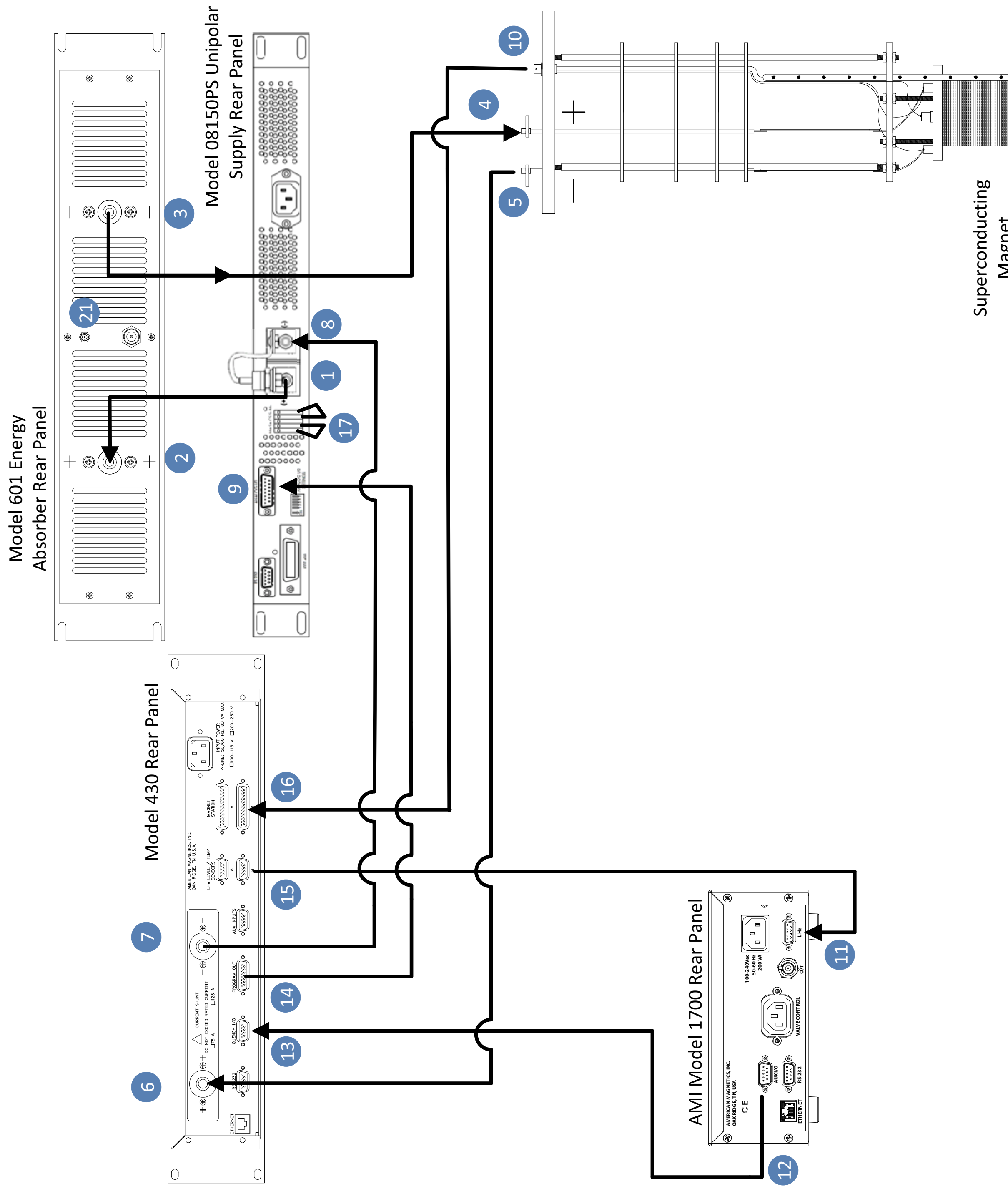


Typical Model 05240PS-430-601 System Rack Interconnections

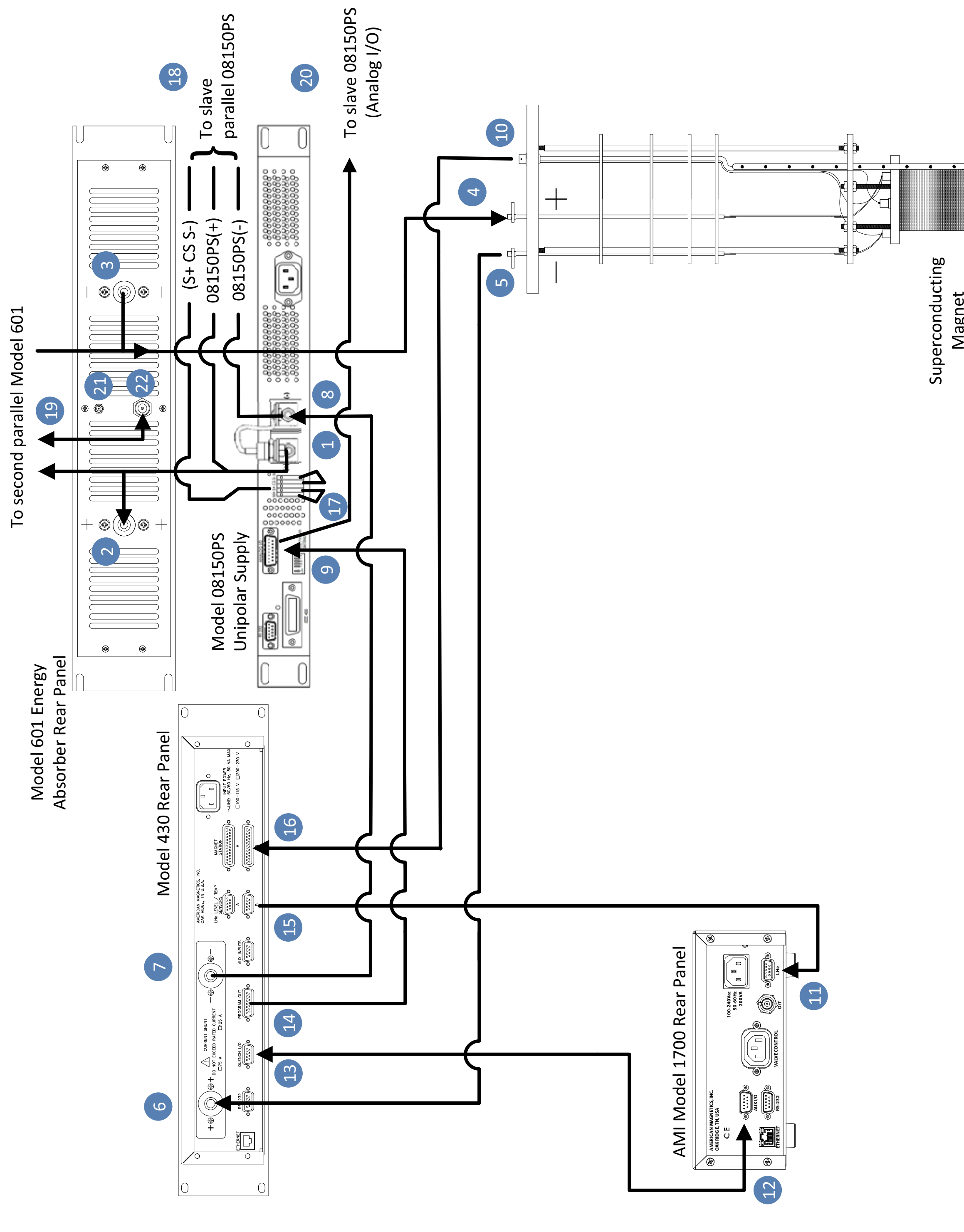
Referring to the diagram on page 29 for the 05120PS system, or page 30 for the 05240PS system,, ensure the cabling is connected in the following manner:

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

CAUTION **Do not overtighten the hardware on the interconnection terminals (refer to specifications table on page 15 for torque limits). Overtightening can result in damage to the terminals.**



Model 05120PS-430-601 Bipolar System Interconnections



Model 05240PS-430-601 Bipolar System Interconnections

WARNING **Ensure the protective diode is installed across the output terminals of the power supply with the anode at the negative (–) terminal and the cathode at the positive (+) terminal. Removal or omission of this protective diode may cause serious injury to personnel and damage to the power supply under loss of AC power conditions.**

a. Connect the Model 601 parallel hardware bus 19 between Model 601 current terminals, plus-to-plus and minus-to-minus.

b. Connect the power supply parallel hardware bus 18 between power supply current terminals, plus-to-plus and minus-to-minus.

c. Connect the protective diode between the output terminal (bus bar on the 05240PS system) of the power supply: anode to the negative (–) terminal (bus on the PS05240PS system) and the cathode to the positive (+) bus terminal or bar.

d. Connect the positive (+) output terminal (bus bar on the 05240PS system) 1 of the power supply to the Model 601 Energy Absorber positive (+) terminal 2.

e. Connect the negative (–) terminal (bus bar on the 05240PS system) 3 of the Model 601 Energy Absorber to the positive (+) magnet current lead 4.

f. Connect the negative (–) magnet current lead 5 to the positive (+) resistive shunt terminal 6 on the back of the Model 430 Programmer.

g. Connect the negative (–) resistive shunt terminal 7 of the Model 430 Programmer to the negative (–) output terminal (bus bar on the 05240PS system) of the power supply 8.

h. *05240PS system only:* Connect Model 05100PS Master unit terminal block positions S+, S-, and CS to their corresponding positions 18 on the Slave unit terminal block.

i. *05240PS system only:* Connect two jumpers 17 from terminal block position S- to M- and from S+ to M+ on the Master[1] power supply unit.

j. Connect the special DB15 analog I/O cable from the PROGRAM OUT connector 14 on the back of the Model 430 Programmer to the DB15 ANALOG I/O connectors 9 on the rear of the Master and Slave 20 (if present) power supply units.

1. Do not add terminal block jumpers to the slave units. Only the single or master unit is jumpered.

k. Install an instrumentation cable between the magnet support stand top plate connector 10 and one of the MAGNET STATION connectors 16 on the rear of the Model 430 Programmer.

l. Optional: Install an instrumentation cable between one of the LHe LEVEL / TEMP connectors 15 on the rear of the Model 430 Programmer and the Model 1700 Liquid Level Instrument LHe connector and/or temperature instrument 11. Refer to page 193.

m. Optional: Install an instrumentation cable between the QUENCH I/O connector 13 on the rear of the Model 430 Programmer and Aux I/O connector 12 on the rear panel of the Model 1700 Liquid Level Instrument. Refer to page 198.

n. Connect Model 601 power adapter 21 and device line cords, and plug them into appropriate power receptacles.

o. On the rear of each parallel Model 601 Energy Absorber, interconnect BNC coaxial connectors 22 with a coaxial cable — no BNC terminators should be used.

p. Remote communications via Ethernet and/or RS-232 can be accomplished by connecting suitable cabling to the Model 430 Programmer rear panel ETHERNET and/or RS-232 connectors.

HIGH-CURRENT, HIGH-STABILITY BIPOLAR POWER SUPPLY SYSTEM

This section illustrates the interconnections for the 05360PS-430-601 (page 34), 05600PS-430-601 (page 35), and 03300PS-430-601 (page 36) power supply systems. A shunt-based current measurement in the Model 430 is not available at greater than 250 A maximum current. An external zero flux current transducer is *required*. In addition to supporting higher currents, the current stability of the system is increased by an order of magnitude.

The high-current, high-stability, bipolar (dual-quadrant) power supply system consists of the Model 430 Programmer with zero flux current sensing, two or more unipolar 08150PS Power Supplies, three or more Model 601 Energy Absorbers, and associated interconnection cabling.

Refer to the diagram on page 37. Ensure the cabling is connected in the following manner:

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

CAUTION **Do not overtighten the hardware on the interconnection terminals (refer to specifications table on page 16 for torque limits). Overtightening can result in damage to the terminals.**

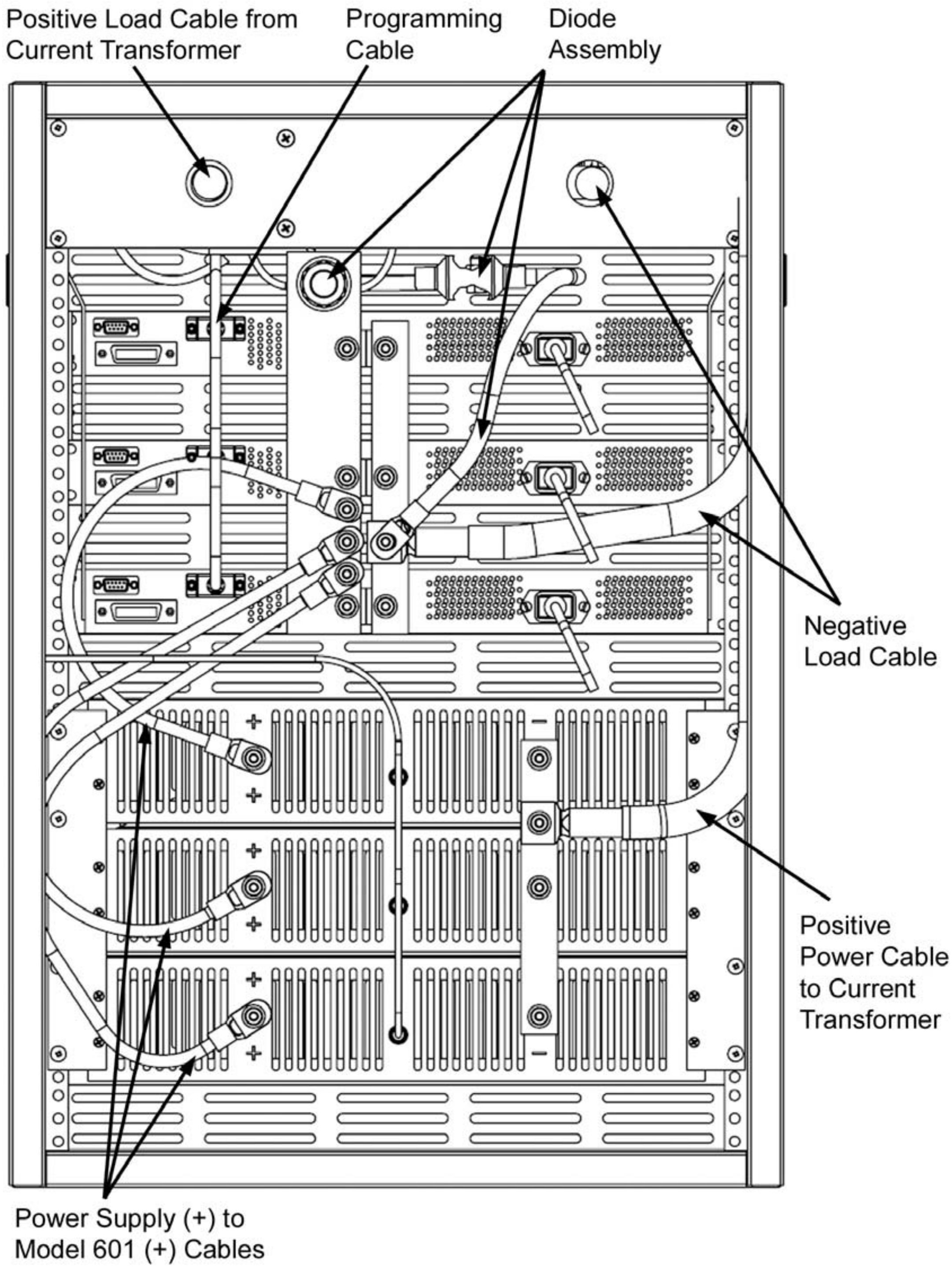
WARNING **Ensure the protective diode is installed across the output terminals of the power supply with the anode at the negative (–) terminal and the cathode at the positive (+) terminal. Removal or omission of this protective diode may cause serious injury to personnel and damage to the power supply under loss of AC power conditions.**

a. Connect 18 the Model 601 parallel hardware bus between Model 601 current terminals, plus-to-plus and minus-to-minus.

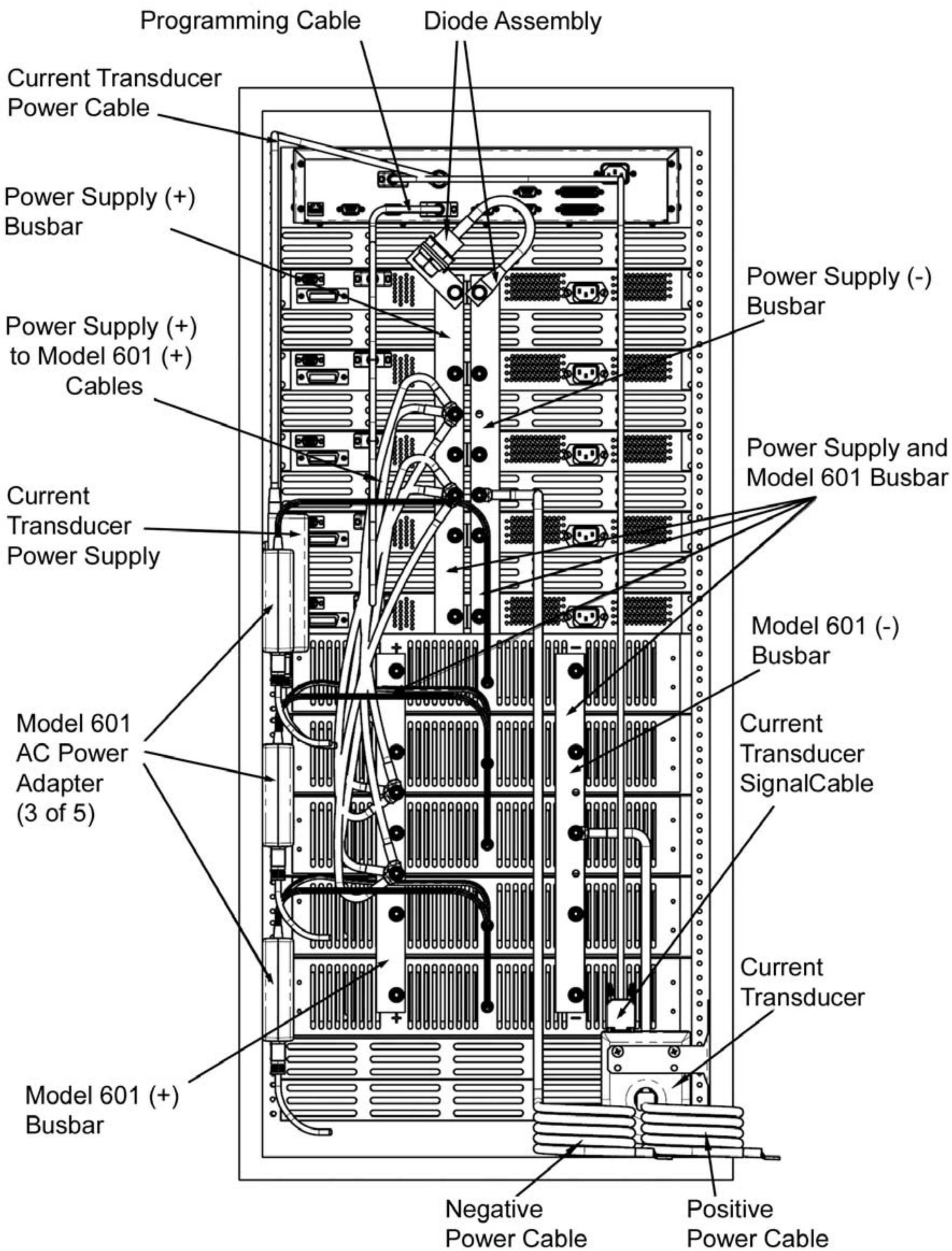
b. Connect 17 the power supply parallel hardware bus between power supply current terminals, plus-to-plus and minus-to-minus.

c. Connect the protective diode between the output busbars of the power supply: anode to the negative (–) terminal and the cathode to the positive (+) terminal.

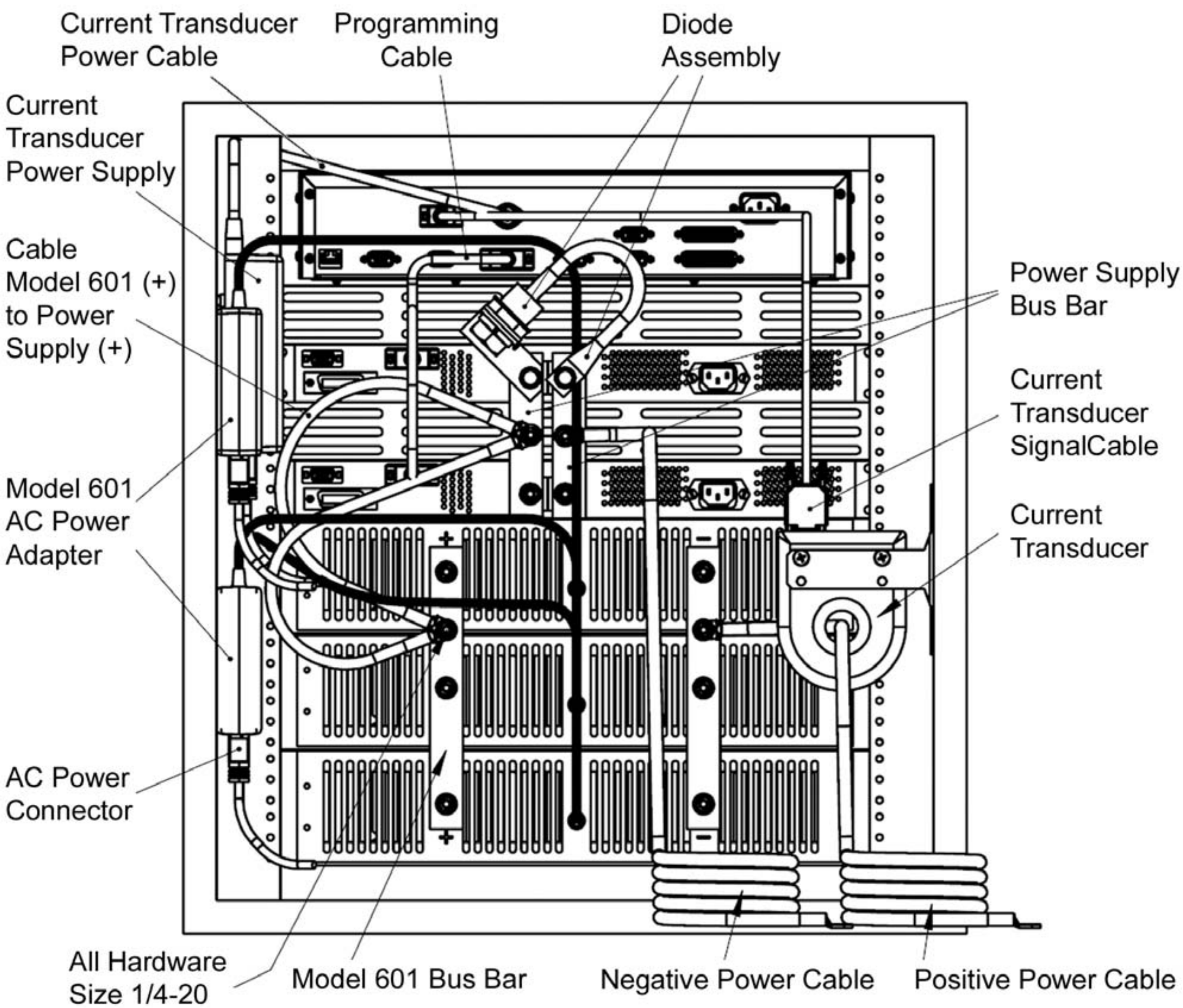
d. Connect the positive (+) OUTPUT bus 1 of the power supply to the positive (+) bus 14 of the Model 601 Energy Absorber.



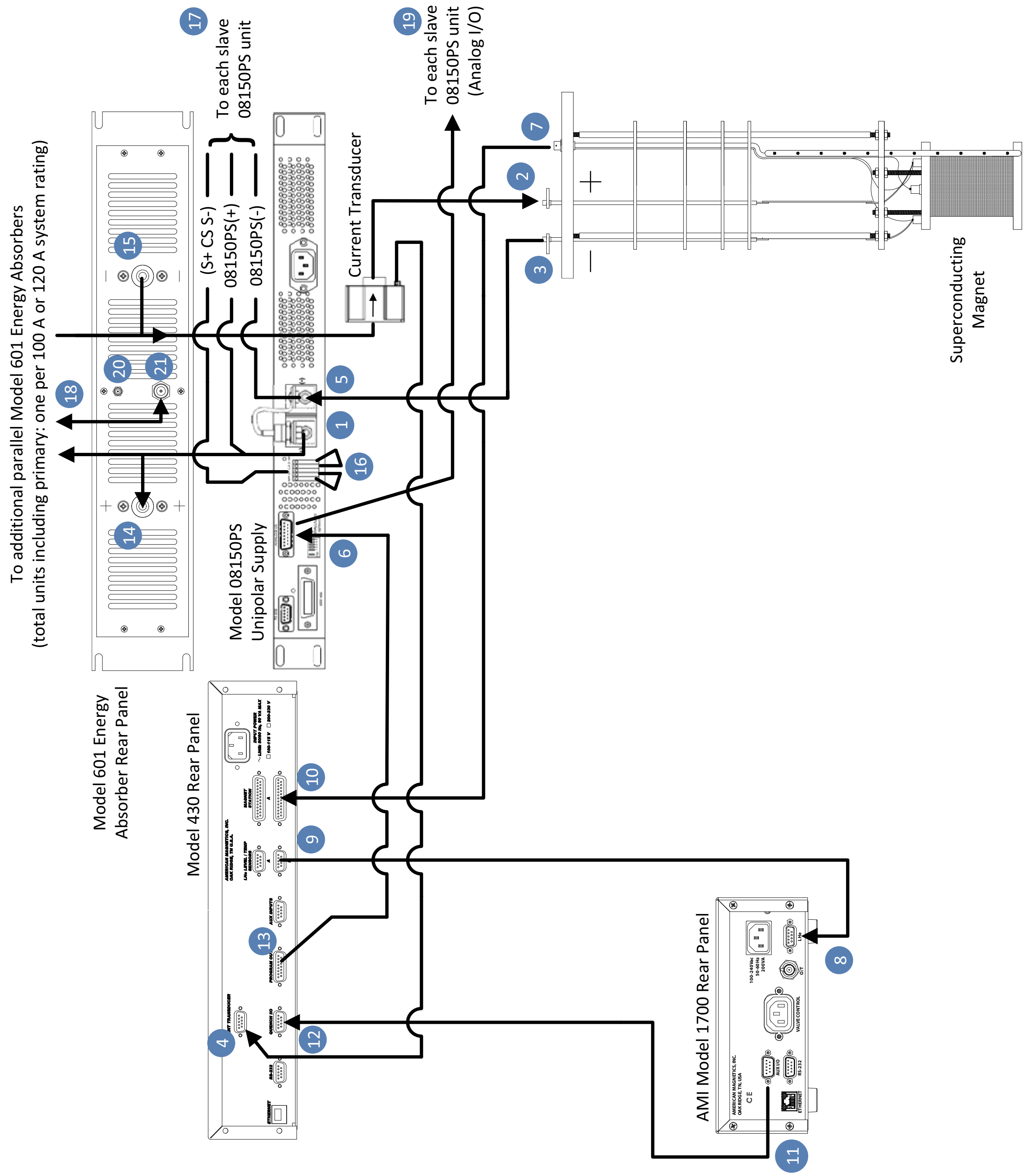
Typical Model 05360PS-430-601 System Rack Interconnections



Typical Model 05600PS-430-601 System Rack Interconnections



Typical Model 03300PS-430-601 System Rack Interconnections



High-Current, High-Stability Bipolar System Interconnections

NOTE **When routing the magnet cable (+) from Model 601 negative (-) bus through the current transducer (CT), the current-direction arrow[2] on the CT must point toward the magnet.**

e. Connect the negative (–) bus 15 of the Model 601 Energy Absorber(s) and route it through the CT (see note). Connect the other end to the positive (+) magnet current lead 2.

f. Connect the negative magnet current lead 3 to the negative power supply bus 5.

g. Connect Model 08150PS Master unit terminal block positions CS, S-, and S+ to each corresponding Slave terminal 17. Connect Master to first Slave, first Slave to second Slave, etc.

h. Connect two jumpers 16 from terminal block position S- to M- and from S+ to M+ on the Master[3] power supply unit.

i. Connect the current transducer output to the current transducer CURRENT TRANSDUCER connector 4 on the rear of the Model 430 Programmer.

j. Connect the special DB15 analog I/O cable from the PROGRAM OUT connector 13 on the back of the Model 430 Programmer to the DB15 ANALOG I/O connectors on the rear of the Master 6 and each Slave 19 power supply unit.

k. Install an instrumentation cable between the magnet support stand top plate connector 7 and one of the MAGNET STATION connectors 10 on the rear of the Model 430 Programmer.

l. Optional: Install an instrumentation cable between one of the LHe / TEMP connectors 9 on the rear of the Model 430 Programmer and the Model 1700 Liquid Level Instrument LHe connector and/or temperature instrument 8. Refer to page 193.

m. Optional: Install an instrumentation cable between the QUENCH I/O connector 12 on the rear of the Model 430 Programmer and the Aux I/O connector on the rear panel of the Model 1700 Liquid Level Instrument 11. Refer to page 198.

n. Connect each device line cord and Model 601 power adapter from the respective device to the appropriate power receptacle.

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2. Corresponding to the conventional current flow direction (electrical current flowing plus-to-minus, opposite that for electron flow).
3. Do not add terminal block jumpers to the slave units. Only the single or master unit is jumpered.

o. Remote communications via Ethernet and/or RS-232 can be accomplished by connecting suitable cabling to the Model 430 Programmer rear panel ETHERNET and/or RS-232 connectors.

SPECIAL CONFIGURATIONS

The Model 430 Programmer has been designed for optimal operation with a superconducting magnet (i.e. a very low resistance, high inductance load) with a persistent switch. The Model 430 Programmer is capable of controlling current to other loads; however, some modification to the Model 430 Programmer settings and/or connections must usually be made. Two commonly encountered configurations are: 1) superconducting magnets without a persistent switch, and 2) operation on a short-circuit or low resistance load.

SUPERCONDUCTING MAGNETS WITH NO PERSISTENT SWITCH

An external stabilizing resistor for superconducting magnets without a persistent switch is no longer required[4]. However, electronically stabilizing such magnets requires a filter that has a differentiating action which can appear to amplify voltage noise across the magnet. If the magnet voltage noise, as indicated by V_m on the Model 430 status screen, is considered excessive for a user's experiment, the user may opt instead to use a stabilizing resistor.

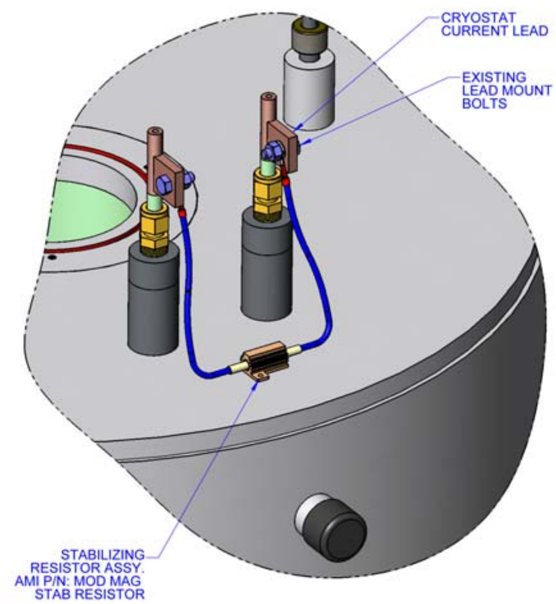
OPTIONAL STABILIZING RESISTOR INSTALLATION

The stabilizing resistor, along with the proper Model 430 configuration, can reduce the apparent voltage noise across the magnet terminals by an order of magnitude or more.

To configure the Model 430 to use the stabilizing resistor, perform the following steps:

4. Effective with Model 430 firmware version 1.62 or later.

1. Place a 20 Ohm resistor, rated for 1W or higher, across the magnet current leads at the top of the cryostat as shown in the figure at right.



Cryostat with Stabilizing Resistor across the Magnet Current Leads

2. Ensure the Model 430 is configured for *no* persistent switch installed (see page 80).

3. Use the `STAB:RES 1` remote command (see page 152) to configure the Model 430 for operation with the stablizing resistor.

   Optionally use the Magnet-DAQ application provided with the Model 430 to indicate a stabilizing resistor is installed (see page 230).

4. Ensure the Stability Setting (see page 76) is configured either by the *Auto* Stability Mode (see page 75), or by manually entering a Stability Setting per the recommendations for magnets *with* a persistent switch installed as shown on page 77.

SHORT-CIRCUIT OR RESISTIVE LOAD

If operating with a short-circuit as a load *without the presence of a superconducting magnet or with the power leads shorted at the cryostat*, the Model 430 Programmer *Stability Mode* must be configured for *Test* (see page 75).

> **NOTE** **If you have purchased a superconducting magnet with the Model 430 Programmer, AMI will normally provide a recommended stability setting for optimal operation of the magnet system. If you operate the Model 430 Programmer with a different load, be sure to restore the Stability Mode and Stability Settings after testing to the AMI-recommended values when the superconducting magnet is reconnected.**

A *special test case* is with the energy absorber designs available from AMI connected to the system. The Model 601 Energy Absorber is a nearly 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 430 Programmer will require an "integration time" to overcome the 5 VDC bias. Once the bias is achieved, the series resistance is minimal, the Model 601 appears as a short-circuit, and test ramping will proceed. It is not possible to avoid this integration time.

However, when operating *with a superconducting magnet in the circuit*, the increased integration gain of the Model 430 Programmer will be adequate to quickly "bias" the Model 601 and achieve a proper current ramping profile. The only time the "integration time" is long is when an energy absorber is connected, and the load is a short circuit.

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 verifying key system components.

1. Using the appropriate diagram from the Installation section 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 may be 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. Often this is most easily accomplished by unfastening the heavy cables from the magnet current leads and fastening them together.[5] This will allow rudimentary power supply checks without energizing the superconducting magnet.

NOTE **It is important that the full length of the power leads to the magnet be connected during the *Test* mode since the leads provide some resistive load (albeit in the tens of mΩ range) for the power supply. The output current of a truly shorted supply output (i.e. zero resistance load) is very difficult to control in voltage mode and may be unstable.**

3. Energize the Model 430 Programmer by placing the power switch in the I (ON) position.

5. If the system shipped with CamLoc quick-disconnect connectors, they may be quickly disconnected from the magnet leads and connected together.

NOTE **If energy absorbers are in use, ensure all the power adapters are properly connected to the energy absorbers and their respective AC power receptacles.**

4. When prompted by the Model 430 Programmer, energize the power supply(s), allow an appropriate amount of time for the supply(s) to start (some produce an audible “click” during power-up), and then press ENTER on the Model 430 Programmer. If there is more than one power supply, observe the proper master/slave power-up procedure.

5. Configure the Model 430 Programmer for *Test* Stability Mode. Refer to page 75.

NOTE **The Model 430 Programmer Stability Mode must be set to *Test* for the power supply system to be stable on a short circuit test load.**

6. Verify the various setup menu values for the system. If the power supply system was purchased with an AMI magnet, AMI has preset the setup menu values for proper operation. See page 69 for more discussion of the setup menu values and their entry into the Model 430 Programmer.

7. Set the Target Setpoint to 10 A. Refer to page 51 and page 58.

8. Initiate ramping to the target current by pressing the RAMP / PAUSE key (status indicator changes from P to †).

9. The system should ramp to 10 A in approximately 2 seconds.[6] Verify this is the case.

NOTE **IfWith an energy absorber unit is connected, the Model 430 Programmer may take significantly longer to ramp the current to 10 A. The Model 430 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 430 control gain is increased by orders of magnitude when an inductive load is connected.**

10. When the target current is achieved, the FIELD AT TARGET LED will be illuminated. The display should show “+10.00 A –” indicating that the Model 430 Programmer is in the holding mode at the target current value (+10.00 A).

11. If the connected power supply has a display, verify that the power supply output current display indicatess that a total of approximately 10 A is being supplied to the load (which is only the cabling in this case).

6. When controlling a magnet, the ramp is very accurate because the system gain is relatively high. When controlling current through a short-circuit, the loop gain is relatively low and it is difficult to track high ramp rates.

NOTE **There may be a discrepancy between the current shown on the power supply display[7] and the current displayed on the Model 430 Programmer. The current measurement system incorporated in the Model 430 is more accurate than the power supply shunt.**

12. Set the Target Setpoint to the Current Limit value. Refer to page 85 to determine the Current Limit value. After the new Target Setpoint current value is entered, the Model 430 Programmer should ramp automatically to the new setting.
13. When the new target current value is reached, the power supply current display (if provided) should also indicate the new value.
14. Press the RAMP TO ZERO key to ramp the system to zero current.
15. Perform remote control software checkout as required.
16. Turn off the power supply(s).
17. Reset the Stability Mode to *Auto* or *Manual* as appropriate for the magnet system to be operated and, if necessary, the parameters for an installed Persistent Switch. Then turn off the Model 430.
18. Remove the short from the power supply leads and connect the leads to the current leads on the cryostat.

After successful completion of this test, the system is ready for operation with a superconducting magnet. Refer to the ramping function example presented on page 118 for a discussion of the various available ramping methods.

7. Not all power supplies have a local current readout.

Operation

This section describes the operation of the Model 430 Programmer. Every menu and submenu item is illustrated and described in detail. An example setup of the Model 430 Programmer is presented on page 105. An example ramping operation is presented on page 118.

NOTE **In some of the examples and figures that follow, the ± sign is used to described various controlled parameter values such as current, ramp rate, etc. Where used to describe currents and fields for *bipolar* power supply systems, the ± should be ignored (considered illustrative only) since the power supply system provides only positive current.**

SYSTEM POWER ON/OFF SEQUENCE

The Model 430 Programmer should always be energized *before* the power supply(s) that it is controlling. The Model 430 Programmer is designed to prompt the user in order to ensure the power supply is energized at the proper time. The Model 430 Programmer should always be de-energized *after* the power supply is shut down.

MODEL 430 PROGRAMMER POWER ON/OFF

Place the Model 430 Programmer power switch in the I (ON) position. After the Model 430 Programmer is powered on and fully initialized (about 20 seconds), the following display will appear:

```
0.00 A  -   Turn on power supply
0.00 Vs     Press ENTER to continue
```

After this screen is displayed, the power supply can be powered up (See "Energizing the Power Supply and Components" on page 46.) *followed by* pressing the ENTER key on the Model 430 Programmer. This brings up the default display.

NOTE **If the display instead appears as illustrated below, turn the Model 430 Programmer off, wait 15 seconds or more, and power the Model 430 Programmer back on.**

```
AMI Model 430 Programmer
FAILURE TO LOAD.
```

When powering the system off, first turn off the power supply controlled by the Model 430 Programmer followed by the Model 430 Programmer. The controller will then ensure the load sees no abnormal power transients as the power supply is turning off.

ENERGIZING THE POWER SUPPLY AND COMPONENTS

WARNING **Do not change power supply jumpers, dip-switches, or other factory settings. If not rack-mounted, always position power supply(s) and Model 601 Energy Absorber(s) for convenience in disconnecting the power cords.**

CHECK THE ZERO FLUX CURRENT TRANSDUCER

If the system includes the High-Stability Option, then a zero flux current transducer is provided. The current transducer must be connected to the Model 430 rear panel CURRENT TRANSDUCER connector.

CAUTION **Operating the system without power applied to the current transducer (CT) can result in loss of control, and may damage the CT.**

The current transducer receives power from the Model 430 Programmer through the CURRENT TRANSDUCER connection (that connects directly to the transducer) on the rear panel of the Model 430 Programmer.

ENERGIZING THE POWER SUPPLY

CAUTION **The master unit must be turned on between 2 to 5 seconds before the slave, otherwise the units will fault and the power-up sequence will have to be repeated.**

Place the power supply switches in the I (ON) position in sequence (see Caution above). No front panel adjustments or connections are required since the power supply control mode and other parameters have been factory-configured for control by the AMI Model 430 Power Supply Programmer.

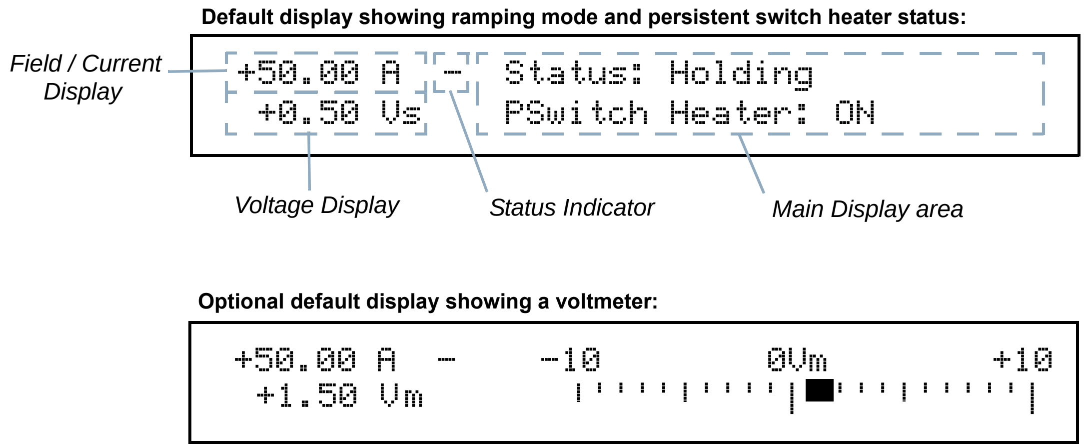
When powering the system off, turn off the power supply(s) (master unit *last*) *before* powering off the Model 430 Programmer.

POWERING THE ENERGY ABSORBER

The Model 601 Energy Absorbers are is operational immediately upon connection to a power receptacle. Power is supplied to the Model 601's by connecting the supplied external DC power converter to the matching connector at the rear of the Model 601, and then connecting the AC power cord to the appropriate power receptacles.

MODEL 430 PROGRAMMER DEFAULT DISPLAY

The default display is illustrated in the figure below. It is displayed whenever no menus are being accessed and no errors are active. The default display can be thought of as being logically divided into four display areas — the Field / Current Display area, the Voltage Display area, the Status Indicator area and the Main Display area.



Illustrations of the default displays

FIELD / CURRENT DISPLAY

The field / current display indicates either the field strength or current[1]. This is always displayed in the upper left corner of the display (see the figure above), regardless of what else is being displayed on the Model 430 Programmer display. The parameter displayed (field or current) is toggled by pressing SHIFT followed by FIELD <> CURRENT.

Thus, if field strength is being displayed, pressing SHIFT followed by FIELD <> CURRENT will cause the current to be displayed; conversely, if current is being displayed, pressing SHIFT followed by FIELD <> CURRENT will cause the field strength to be displayed.

Operating current is always displayed in amperes (A). Operating field strength may be displayed in kilogauss (kG) or tesla (T) if a coil constant has been specified in the setup[2]. If field strength is being displayed, the units (kG or T) in which it is displayed can be toggled by pressing SHIFT followed by FIELD UNITS.

NOTE **The displayed field strength is not directly measured, but rather is calculated by multiplying the coil constant entered in the setup menu by the measured current flow of the Model 430 power supply system.**

1. The value is always displayed in current (A) when an installed persistent switch is in the *cooled state* since the value represents power supply current only, independent of the stored (i.e. persistent) magnet current/field.
2. Refer to page 78.

VOLTAGE DISPLAY

The voltage display indicates either the voltage across the magnet (Vm) or the power supply output voltage (Vs). This is always displayed in the lower left corner of the display (see the figure on page 48), regardless of what else is being displayed on the Model 430 Programmer display.

The parameter displayed (magnet voltage or power supply voltage) is toggled by pressing SHIFT followed by Vs <> Vm (i.e. SHIFT+0).

NOTE **The right and left arrow keys can also be used to toggle the Voltage Display area to show the present temperature in Kelvin as optionally read via the Auxiliary Input 3. For more details, see page 88.**

Vm indicates the voltage measured across the terminals of the connected superconducting magnet. In order for the Model 430 Programmer to measure the magnet voltage, the magnet voltage taps must be connected to the Model 430. Normally this is done through the Magnet Station Cable provided by AMI (if the whole magnet system is provided by AMI). Vs indicates the Model 430 Programmer-controlled power supply output voltage.

NOTE **The displayed power supply voltage (Vs) is not directly measured, but rather is calculated based on power supply control voltage being provided by the Model 430 Programmer and the power supply input control voltage and output voltage values entered in the setup menu.**

STATUS INDICATOR

Description of Status Indicators

P	Paused
↑	Ramping Up
↓	Ramping Down
−	Holding
⁘	Heating Persistent Switch
	Cooling Persistent Switch
V	Voltage Limited
C	Current Limited
T	Temperature Limited

The status indicator displays the Model 430 Programmer operating status. It is always visible (except during a quench condition) and is displayed just to the right of the field / current display (see the figure on page 48). The status indicator may be one of the symbols indicating a condition as described in the table at left.

If the ramping mode character is blank, then a quench condition exists and the red MAGNET QUENCH LED on the front panel will be illuminated.

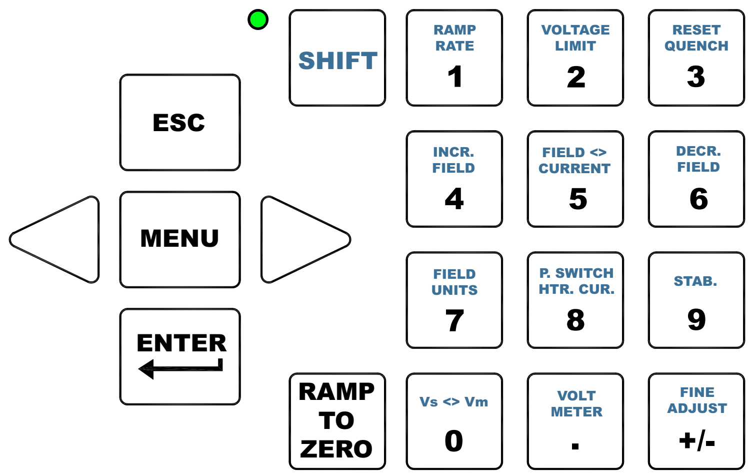
See page 107 for a more detailed discussion of the meaning of the ramping modes (Paused, Ramping Up, Ramping Down and Holding).

MAIN DISPLAY

The default main display (the rightmost portion of the display – see the figure on page 48) shows either a voltmeter indicating magnet voltage or ramp mode and persistent switch heater state. Ramp mode is displayed on the top line of the main display; it will be one of ten states, as listed in the table on page 108.

The persistent switch heater state is displayed on the bottom line of the main display. If the Model 430 Programmer has been setup for use with a persistent switch, it will indicate either ON or OFF for the persistent switch heater state; otherwise, it will display “No PSwitch Installed.”

ENTERING NUMERIC VALUES



Numeric Keypad and Associated Keys

A consistent method of entering values is used within menus requiring numeric entries. Once a menu is selected, the user may start an entry by pressing a digit (0 through 9), the decimal key (.), or the sign key (+/-).[3] The display will begin a new entry and display a cursor (_) as a prompt for the next digit or decimal entry. Also, once entry is initiated, the display will show an asterisk (*) indicating that numeric entry is *active*.

Alternately, the ENTER key may be pressed before any of the numeric keypad keys; the display will begin a new entry and display a cursor (_) as a prompt for the next digit or decimal entry, and the display will show an asterisk (*) indicating that numeric entry is *active*.

An example of a numeric entry in progress (numeric entry active) is illustrated below:

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

Once the numeric value has been entered, press the ENTER key to accept the numeric value. Values are *not* applied to the operation of the Model 430 Programmer until the ENTER key is pressed and the asterisk disappears from the display. Attempts to set a parameter to a value

3. Certain menu items requiring numeric data can also be entered using the fine adjust knob (see page 52).

outside of the valid range are ignored, and if attempted the Model 430 Programmer will beep once, indicate the error, and revert to the previous setting.

If the ESC key is pressed while numeric entry is active and digits have been entered, the entered digits will be cleared and the cursor will remain for reentry of a new desired value. If the ESC key is pressed with *no* entered digits on the display, the setting will revert to the previous value and numeric entry will be made inactive.

Thus, if digits have been entered, the first time ESC is pressed, the entered digits are cleared, but numeric entry remains active; if ESC is then pressed again (with no entered digits displayed), the setting reverts to its previous value and numeric entry is made inactive.

Note that if the ESC key is pressed when numeric entry is *not* active, the current submenu will be exited and the next higher level submenu will be entered.

USING THE FINE ADJUST KNOB

For menu items requiring entry of a numeric value, the value may alternatively be adjusted with the front panel fine adjust knob. These menu items include:

- Target Field Setpoint (in holding mode or while ramping)
- Voltage Limit
- Ramp Rate (if there is no PSwitch or if PSwitch is fully heated). Disallowed during switch heating/cooling transition.
- Custom Supply Menu (Min Output Voltage, Max Output Voltage, Min Output Current, Max Output Current)
- Stability Setting
- Coil Constant
- Current Limit
- PSw P/S Ramp Rate if PSwitch is fully cooled. Disallowed during switch heating/cooling transition.
- PSwitch Current
- PSwitch Heated Time
- PSwitch Cooled Time
- PSwitch Cooling Gain

Instead of entering a value using the numeric keypad, the operator can press the SHIFT key, followed by FINE ADJUST (i.e SHIFT +/-). The display will then show an up/down arrow (⇕) indicating that the fine adjust knob is active.

When the fine adjust knob is live, adjustments made using it take place *immediately*. This can be a useful and powerful functionality. Any numeric value can be incrementally adjusted using the fine adjust knob, and its affect on the system can be observed *as the adjustment is being made*.

For example, with the persistent switch heater on, the persistent switch heater current can be adjusted incrementally to find the persistent switch heater superconducting/normal thresholds.

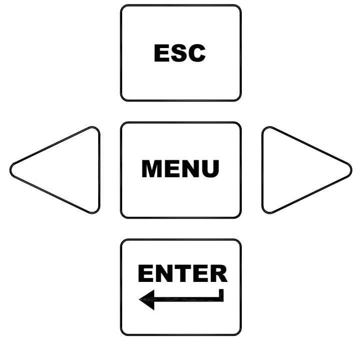
An example of a fine adjust in progress (fine adjust knob is live) is illustrated below:

```
+50.00 A   -  PSwitch Current (mA)↕
 +0.50 Vs       46.7
```

NOTE **The fine adjust knob is velocity-sensitive, meaning that the faster the knob is turned, the more coarse the adjustment. Slow manipulation of the knob will yield very fine resolution even beyond that displayed by the Model 430 Programmer.**

When the desired numeric value has been set using the fine adjust knob, the ENTER key is pressed to store the value. Pressing the ESC key while the fine adjust knob is live will cause the adjusted value to revert to its previous setting and make the fine adjust knob inactive. In fact, pressing *any* key other than ENTER will cause the adjusted value to revert to its previous setting and make the fine adjust knob inactive.

SELECTING PICKLIST VALUES



Menu Navigation Keys

Some submenu items require the user to select a value from a list of predefined values (picklist values). Such menus will display an item selector (▶) which points to the picklist value currently selected. To change the value to another value in the picklist, first press the ENTER key; the display will show an asterisk (*) indicating that picklist entry is *active and can be edited*.

While picklist entry is active, the left and right *keypad* arrows (to the left and right of the MENU key) move the item selector between the different picklist values. Pressing the left keypad arrow moves the item selector one picklist value to the left and pressing the right keypad arrow moves the item selector one picklist value to the right.

When the last picklist value is reached, and the right keypad arrow is pressed, the item selector will move to the first picklist value. Likewise, when the item selector is pointing to the first picklist value, and the left keypad arrow is pressed, the item selector will move to the last picklist value.

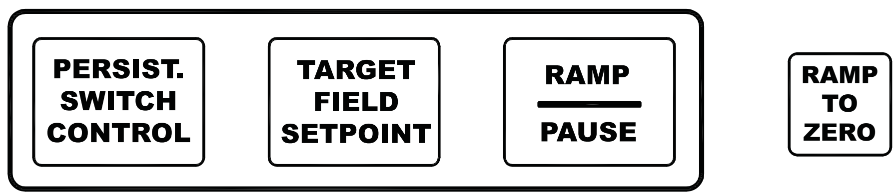
An example of a picklist entry in progress (picklist entry active) is illustrated below:

```
+50.00 A   -  Field Units*
 +0.50 Vs     ▶Kilogauss   Tesla
```

When the item selector is pointing at the desired picklist value, press the ENTER key to accept the picklist value. Values are *not* applied to the operation of the Model 430 Programmer until the ENTER key is pressed and the asterisk disappears from the display.

If the ESC key is pressed while picklist entry is active, the setting will revert to the previous value and picklist entry will be made inactive. Note that if the ESC key is pressed when numeric entry is *not* active, the current submenu will be exited and the next higher level submenu will be restored (if it exists).

SINGLE-KEY COMMANDS / MENUS



Single Input Keys

All ramping controls (PERSIST. SWITCH CONTROL, TARGET FIELD SETPOINT, RAMP / PAUSE and RAMP TO ZERO) are accessed with a single keystroke. See page 107 for details of ramping controls. Below is a brief summary of the function of each of these keys.

PERSISTENT SWITCH CONTROL KEY

Pressing the PERSIST. SWITCH CONTROL key toggles the Model 430 Programmer persistent switch heater control function.

If the persistent switch heater is energized and this key is pressed, the persistent switch heater is de-energized. The power supply output is then maintained for the time set by the PSwitch Cooled Time setting before being ramped down to zero at the PSw P/S Ramp Rate setting (default rate is 10 A/sec).

If the persistent switch heater is de-energized and this key is pressed, the power supply is ramped to the current present in the magnet when the switch was cooled at the rate set by the PSw P/S Ramp Rate and then the persistent switch heater is energized.

NOTE **Since the magnet is isolated from the power supply output while the persistent switch is in the cooled state, it is possible to ramp the power supply output current up/down at the much faster PSw P/S Ramp Rate setting.**

Pressing SHIFT followed by the PERSIST. SWITCH CONTROL key toggles the Model 430 Programmer persistent switch heater between energized (turned on) and de-energized (turned off). If the persistent switch heater is energized and this key is pressed, the persistent switch heater is de-energized. If the persistent switch heater is de-energized and this key is pressed, the persistent switch heater is energized.

NOTE **The power supply output current remains unchanged when** SHIFT + PERSIST. SWITCH CONTROL **is used. Only the state of the persistent switch heater is changed.**

When the persistent switch heater is energized, the Model 430 Programmer 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, which takes the magnet out of persistent mode. Magnet persistent mode is indicated by the MAGNET IN PERSISTENT MODE LED[4].

The Model 430 Programmer 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 Switch submenu and specifying the switch heating current, switch transition detect method, and the heated time and cooled time[5] for timer-based transitions.

The nominal switch heating current is listed on the magnet specification sheet, and may be entered in the Model 430 Programmer by accessing the Switch submenu[6]. In addition to the *heating current*, the user must also specify the *switch transition* detection method, *PSw P/S Ramp Rate* and *cooling gain*. If the switch transition is timer-based, then the *heated time* and *cooled time* must also be specified.

TIMER-BASED SWITCH TRANSITIONS

The heated time allows the Model 430 Programmer to delay compensating the internal control logic until the magnet is guaranteed to be in the circuit. The heated time can be set from a minimum of 5 seconds to a maximum of 120 seconds within the Load submenu[7]. The default heating period of 20 seconds is adequate for the majority of persistent switches. If the magnet appears unstable just after the switch heating period expires, increase the switch heated time to allow for complete heating.

The cooled time allows the persistent switch sufficient time to be cooled to superconducting state before the current is changed in the magnet. The cooled time can be set from a minimum of 5 seconds to a maximum of 3600 seconds within the Load submenu[8]. The default cooling period of 20 seconds is adequate

4. See page 67.
5. See page 80 and page 82.
6. See page 82.
7. See page 83.

for the majority of wet persistent switches. Conduction-cooled switches may require longer times to transition from resistive to superconducting state and can benefit from direct magnet voltage-based transition detection as described below.

During timer countdowns, the remaining time in seconds is displayed in the default display status area. A value of (0) indicates the respective timer has expired.

MAGNET VOLTAGE-BASED SWITCH TRANSITIONS

For magnet voltage-based switch detections, a running average and variance of the magnet voltage is calculated. If the running average is less than 0.5 mV *and* the variance is less than an adjustable preset limit (typically 10 nV^2), the switch is considered in the cooled state. The variance must exceed four times (4x) the preset limit to be considered as exiting the cooled state.

The average *and* variance limits essentially describe a constant magnet voltage of zero (0) volts given the internal Model 430 resolution of the voltage measurement, which is the expected value a cooled persistent switch should exhibit. An additional safety factor delay of 5 seconds is added for each transition once the limits are exceeded.

Magnet voltage-based transition detection *requires* magnet voltage taps connected to pins 11 & 12 of the Magnet Station connector as described on page 192.[9]

During magnet voltage-based transitions, the running variance in nanovolts^2 (nV squared) is shown in the default display status area. A continuous value of (0) indicates a cooled switch state.

The default cooling gain of 0.0% may be adequate for the majority of wet persistent switches. However, this setting may result in some magnet drift during persistent switch cooling, especially with conduction cooled switches. Increasing the cooling gain adds control loop gain during the switch cooling cycle. Too little may result in magnet drift during switch cooling. Too much may result in power supply instability during switch cooling, which could potentially prevent the switch from cooling. Most systems requiring some cooling gain to control magnet drift will likely work with value set to 25%.

8. See page 83.
9. The additional provision of connecting the magnet voltage taps to Auxiliary Input 1 must be addressed if using a Model 430 with firmware prior to version 3.00. See page 200.

NOTE **During the period the switch is being heated or cooled, the Model 430 Programmer will not allow ramping functions to be executed, and will beep once and indicate an error if the user attempts to initiate a ramping operation.**

Refer to page 110 for a complete description of magnet persistent switch control.

Target Field Setpoint Key

Pressing the TARGET FIELD SETPOINT key provides a menu for setting the target field/current. The target field/current is the field or current to which the Model 430 Programmer ramps the superconducting magnet when it is not paused. The target field/current may be set equal to or less than the Current Limit[10] or equivalent field (per defined coil constant). The target field/current does not require a sign (attempting to enter a negative value will cause the Model 430 Programmer to produce one beep and indicate an error).

```
+50.00 A   -   Target Field (kG)
 +0.50 Vs        +50.000
```

When on the default display, pressing the SHIFT + TARGET FIELD SETPOINT keys will display the Magnet Current/Field for three seconds before reverting to the default display. Pressing any key will clear the display. The value displayed is as follows:

- When in driven mode, the present current/field will be displayed.
- When in persistent mode, the current/field displayed is the value that was circulating in the magnet at the time persistent switch was cooled.

```
 +0.25 A   P   Magnet Current (A)
  0.00 Vs        +10.00 A
```

Ramp / Pause Key

Pressing the RAMP / PAUSE key toggles the Model 430 Programmer between the ramping mode and the paused mode. If the RAMP / PAUSE key is pressed while the Model 430 is ramping, the ramping is paused. If the RAMP / PAUSE key is pressed while the Model 430 is paused, the Model 430 continues ramping.

10. See page 85.

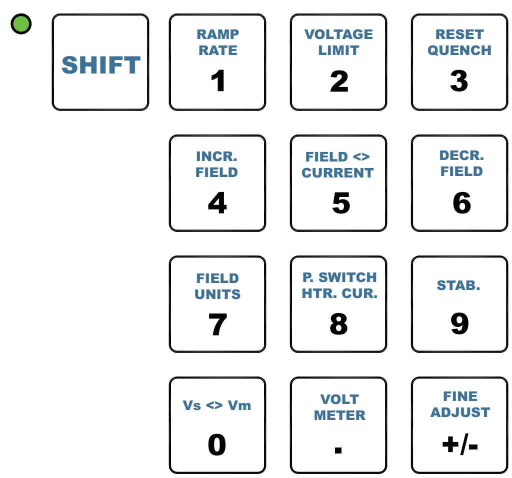
RAMP TO ZERO KEY

Pressing the RAMP TO ZERO key causes the Model 430 Programmer to immediately begin ramping field/current up or down to zero field/current at the defined ramp rate(s). Ramping to zero may be interrupted at any time by pressing the RAMP / PAUSE key, which causes the Model 430 Programmer to enter the PAUSED mode and maintain the field/current present at the point it was paused.

NOTE **If the RAMP TO ZERO function is paused and then the RAMP / PAUSE button is pressed a second time, the Model 430 Programmer will begin ramping to the target field, not to zero. If it is desired to ramp to zero after the RAMP / PAUSE button is pressed, press the RAMP TO ZERO button again to continue ramping to zero from the paused state.**

NOTE **If the magnet is persistent (i.e. switch heater is not energized) when the RAMP TO ZERO key is pressed, the Model 430 Programmer ramps the power supply current to zero; the magnet current will remain constant since the magnet is in persistent mode.**

SHIFT+KEY COMMANDS / MENUS



SHIFT+Key Functions

The most commonly used commands and menus (other than ramping controls) are accessed using the SHIFT key followed by a numeric keypad key. Use of the specific SHIFT+key commands and menus is described in sections specific to the functionality of that specific SHIFT+key combination.

In general, a SHIFT+key command is executed or a menu is accessed by first pressing the SHIFT key (which turns on the SHIFT LED), and then pressing[11] one of the keys of the numeric keypad (0 through 9, ".", or "+/-"). The SHIFT+key command / menu for each key of the numeric keypad is shown in light blue text at the top of each key.

To access the voltage limit menu, for example, press the SHIFT key, and then press the VOLTAGE LIMIT key (also the 2 key). Note that some of the SHIFT+key menus can also be accessed using the setup menu.

Pressing the ESC key or the SHIFT key a second time will clear the SHIFT function and return the keypad to it's numeric function.

RAMP RATE (SHIFT+1)

Use of the RAMP RATE (SHIFT+1) key provides a menu for setting ramp rate(s). The ramp rate may be set[12] within the range specified for the specific Model 430 Programmer configuration (refer to the specifications on page 17). If field units are being used, then the ramp rate setting is displayed and set in units of kG/sec or T/sec).

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 in the table on page 17. If the Ramp Segments value[13] is greater than 1, then the menu also allows setting of the field or current range for each ramp rate segment.

The Model 430 Programmer 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 430 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.

RAMP RATE EXAMPLE

An example (using a magnet with rated current of 60 A[14]) will illustrate the use of the ramp rate menus. The example assumes that the field/current units have been set to amperes and the ramp segments value has been set to three (3) segments. The ramping is chosen with rates as follows:

1. ±0.2 A/s from 0 to ±55 A
2. ±0.1 A/s from ±55 to ±58 A
3. ±0.05 A/s above ±58 A.

11. Note the SHIFT key plus the following key-press are sequential, not simultaneous.
12. Using numerical keys as described on page 51 or the fine adjust knob (page 52).
13. See page 92.
14. In this example, the Current Limit is set at the rated magnet current of 60 A.

In the following discussion, the fine adjust knob[15] can optionally be used for ramp rate adjustment if the persistent switch is heated (or if no persistent switch is installed). If the user attempts to edit ramp rate segments using the fine adjust knob while an installed switch is cooled, the Model 430 Programmer will produce one beep to indicate an error[16]. Similarly, if the switch is heated (or no switch is installed), attempting to use the fine adjust knob for PSw P/S ramp rate will produce one beep[17].

Pressing SHIFT and then RAMP RATE will access the ramp rate menu. The numeric and ENTER keys (or the fine adjust knob) are used to set the segment #1 ramp rate to a value of 0.2 A/sec.

```
+50.00 A  -  Seg.1 Ramp Rate (A/sec)
 +0.50 Vs     ±0.2000
```

The right arrow key is pressed once to access the segment #1 range display. The numeric and ENTER keys (or fine adjust knob) are used to set the segment #1 current range upper bound to a value of 55 A.

```
+50.00 A  -  Seg.1 Range (A)
 +0.50 Vs    0.0 to ±55.0
```

Pressing the right arrow key accesses the next (second) segment ramp-rate display. The segment #2 ramp rate is set to a value of 0.1 A/sec.

```
+50.00 A  -  Seg.2 Ramp Rate (A/sec)
 +0.50 Vs     ±0.1000
```

The right arrow key is pressed once to access the segment #2 range display. The segment #2 current range upper bound is set to a value of 58 A.

```
+50.00 A  -  Seg.2 Range (A)
 +0.50 Vs    ±55.0 to ±58.0
```

15. See page 52.
16. Since the PSw P/S ramp rate is active in that scenario, and not the segmented ramp rate.
17. Since the standard segmented ramp rate is active in that scenario, and not the PSw P/S ramp rate.

Pressing the right arrow key accesses the next (third) segment ramp rate display. The segment #3 ramp rate is set to a value of 0.05 A/sec.

```
+50.00 A   -   Seg.3 Ramp Rate (A/sec)
 +0.50 Vs       ±0.0500
```

Pressing the right arrow key accesses the segment #3 current range display.

NOTE **If there is more than one segment, the upper bound of the last segment is always the Current Limit[18] and it will be displayed as "±Limit" as shown below and cannot be edited.**

```
+50.00 A   -   Seg.3 Range (A)
 +0.50 Vs      ±58.0 to ±Limit
```

Now, when current is in the range of 0 to ±55 A, ramping will be controlled at ±0.2 A/sec. When current is in the range of ±55 to ±58 A, ramping will be controlled at ±0.1 A/sec and when current is greater than ±58 A (up to the limit of 60 A), ramping will be controlled at ±0.05 A/sec.

If ramp rate of a ramp segment is being edited while the Model 430 is ramping and the system current/field transitions from the currently edited segment to the next before the adjustment has been committed with the ENTER key, the adjusted value *will be discarded*. The display will update to show the new segment ramp rate, and the fine adjust knob will apply to the new segment (assuming the ENTER key is pressed before the segment has completed).

If at some later time it is desired to set the Current Limit to a value less than 58 A, only the first two ramp segments would remain active since the new "limit" falls within the range of segment #2. The display for segment 2 range would then appear as follows[19].

```
+50.00 A   -   Seg.2 Range (A)
 +0.50 Vs      ±55.0 to ±Limit
```

18. Refer to page 85.
19. If the Current Limit were to be set below 55 A, only segment #1 would be active, and would display the upper bound of "±Limit".

Any unused segment(s) above the Current Limit will remain in memory (retaining their original parameters) until one or more become active again when the Current Limit is raised into or above the respective ranges. When displayed, the higher-range *unused* segments will show a range of “±Limit to ±Limit” until re-activated[20].

```
+50.00 A   -   Seg.3 Range (A)
 +0.50 Vs      ±Limit to ±Limit
```

VOLTAGE LIMIT (SHIFT+2)

Use of the VOLTAGE LIMIT (SHIFT+2) key provides a menu for setting the limit for output voltage for the power supply the Model 430 Programmer controls. This value should be set to a high enough value so that under normal conditions, the Voltage Limit is never reached. The value can be set by using either the numeric keypad entry as described page 51 or the fine adjust knob (on page 52).

Note that the voltage drop in the leads must be accounted for when setting the Voltage Limit, as well as the voltage drop of an energy absorber if in use (see page 107 for details of how to determine the appropriate Voltage Limit).

```
+50.00 A   -   Voltage Limit (V)
 +0.50 Vs       ±2.000
```

The Voltage Limit may be set less than or equal to the maximum output voltage of the power supply.[21] The Voltage Limit functions as a bipolar limit.

If Voltage Limit becomes active while ramping, it will be indicated by a reverse illumination character “V” for the status indicator.

```
+40.92 A   ↑   Mode: Ramping
 +2.50 Vs  V   PSwitch Heater: ON
```

Once the Voltage Limit function becomes active, the current, and therefore field, will no longer be ramping linearly with time as the voltage available to charge the magnet will be reduced as the total loop voltage

20. Also if the number of segments is increased, the new segments are added to the upper end of the ramp range, and default to the ramp rate of the previous segment with the range of ±Limit to ±Limit until set up.
21. Refer to the table on page 72.

will be limited. As the *i x R* drop of the leads increases with current, the voltage available to charge the magnet will be reduced.

RESET QUENCH (SHIFT+3)

The RESET QUENCH (SHIFT+3) key is used whenever a quench detection has occurred and is being indicated on the display (example shown below).

```
0.00 A   -   Quench Detect @ +45.81 A
0.00 Vs      PSwitch Heater: ON
```

When a quench detection has occurred, the Model 430 Programmer will respond to no further input until the RESET QUENCH key is pressed, or until the quench condition is cleared by a remote command. For more discussion of quench detection see page 120.

INCREMENT FIELD (SHIFT+4)

The INCR. FIELD (SHIFT+4) key is used to manually increase the field. This is done at the defined ramp rate(s).

When the INCR. FIELD key is pressed, the current/field begins ramping up. If the INCR. FIELD key is pressed again (while the current/field is manually ramping up), the ramping will be paused. Alternately, the RAMP / PAUSE key may be pressed to pause manual ramping. Manual ramping will continue until paused or the Current Limit[22] is achieved.

FIELD <> CURRENT (SHIFT+5)

The FIELD <> CURRENT (SHIFT+5) key is used to toggle between the use of field units, either kG (kilogauss) or T (tesla), and the use of current units (A)[23]. If the Model 430 Programmer is using field units (either kG or T) and the FIELD <> CURRENT SHIFT-key is pressed, the Model 430 Programmer will begin using current units (A). Conversely, if the Model 430 is using current units (A) and the FIELD <> CURRENT SHIFT-key is pressed, the Model 430 will begin using field units (either kG or T).

NOTE **The Model 430 Programmer cannot use field units unless a valid coil constant has been entered[24].**

22. See page 85.
23. The value is always displayed in current (A) when an installed persistent switch is in the *cooled state* since the value represents power supply current only, independent of the stored (i.e. persistent) magnet current/field.
24. See page 78.

DECREMENT FIELD (SHIFT+6)

The DECR. FIELD (SHIFT+6) key is used to manually decrease the current/field. This is done at the defined ramp rate(s).

When the DECR. FIELD key is pressed, the current/field begins ramping down. If the DECR. FIELD key is pressed again (while the current/field is manually ramping down), the ramping will be paused. Alternately, the RAMP / PAUSE key may be pressed to pause manual ramping. Manual ramping will continue until paused or zero current/field is achieved.

FIELD UNITS (SHIFT+7)

Use of the FIELD UNITS (SHIFT+7) key provides a shortcut to the picklist menu[25] for defining whether the field is specified and displayed in units of kilogauss (kG) or tesla (T). The selected option also applies to remote interface commands. The default setting is kilogauss.

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

PERSISTENT SWITCH HEATER CURRENT (SHIFT+8)

Use of the P. SWITCH HTR. CUR. (SHIFT+8) key provides a shortcut to the menu[26] for setting persistent switch heater current. The value can be set to between 0.0 and 125.0 mA. The default value is 10.0 mA unless preset by AMI to match a specific superconducting magnet.

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

STABILITY (SHIFT+9)

Use of the STAB. (SHIFT+9) key provides a shortcut to the menu for defining the Model 430 stability setting. The stability setting is specified in percent and controls the transient response and stability of the system. The valid input range is from 0.0 to 100.0%. The default value is 0.0% unless preset by AMI to match a specific superconducting magnet.

See page 76 for details of how to determine the stability setting to use.

VS <> VM (SHIFT+0)

The Vs <> Vm (SHIFT+0) key is used to toggle the voltage display between display of the voltage across the magnet (Vm) and the power supply output voltage (Vs). See page 49 for details.

25. See page 93.
26. See page 82.

VOLT METER (SHIFT+.)

The VOLT METER (SHIFT+.) key is used to toggle the main display between display of a voltmeter indicating magnet voltage (Vm) or supply voltage (Vs), and display of ramp mode and persistent switch heater state. See page 50 for details.

FINE ADJUST (SHIFT +/-)

The FINE ADJUST (SHIFT +/-) key is used to enable the use of the front panel fine adjust knob to adjust numeric values. See page 52 for details.

SHIFT + PERSIST. SWITCH CONTROL

This keystroke enables persistent switch control *without* some automatic sequencing features. Refer to page 55.

LED INDICATORS

The Model 430 Programmer has six front panel LED indicators. See the front panel illustration and table on page 10 for the location of these indicators.

POWER-ON INDICATOR

The green power-on LED indicates that the Model 430 Programmer is powered on.

MAGNET STATUS INDICATORS

Four LEDs are grouped together to show the magnet status.

Magnet Status LED Indicators

FIELD AT TARGET INDICATOR

The green FIELD AT TARGET LED indicates that the current is at the target value. If the magnet is not in persistent mode (persistent switch heater is on), then this is an indication that the magnet field has reached the target value. If the magnet is already in persistent mode, then this is an indication that the current being supplied to the magnet system has reached the target value.

MAGNET IN PERSISTENT MODE INDICATOR

CAUTION **If the Model 430 Programmer power is turned off while the persistent switch is heated, persistent switch heating will be lost and the magnet will enter persistent mode. The Model 430 will not have a record of that event. Therefore the** MAGNET IN PERSISTENT MODE **LED state will be incorrect (remain OFF) when the Model 430 Programmer power is restored.**

CAUTION **If the Model 430 Programmer power supply system is powered off and moved from one magnet system to another, the MAGNET IN PERSISTENT MODE LED may not correctly indicate the state of the magnet system until the first time the persistent switch heater is turned off.**

NOTE **Should the magnet quench while the magnet is in persistent mode and the Model 430 Programmer is off, the persistent mode indicator LED will be incorrect when the Model 430 Programmer is turned on again.**

The green MAGNET IN PERSISTENT MODE LED indicates that the persistent switch heater is off, and that when it was turned off, the magnet had greater than 0.1% of the maximum system current[27] flowing through it. The state of this LED is kept in nonvolatile memory when the Model 430 is powered off, so that the LED state is retained even during a power cycle of the Model 430. Thus, the MAGNET IN PERSISTENT MODE LED is an indicator that the magnet is persistent and has at least *some* persistent field.

CURRENT LEADS ENERGIZED INDICATOR

The blue CURRENT LEADS ENERGIZED LED indicates that at least 0.1% of the maximum system current[28] is flowing in the Model 430 power supply system output current leads.

MAGNET QUENCH INDICATOR

The red MAGNET QUENCH LED indicates that a magnet quench condition has been detected. See page 120 for details.

SHIFT INDICATOR

The green SHIFT LED indicates that the SHIFT key has been pressed, and the next numeric keypad key pressed will actuate the shifted function (shown in light blue text on the key label) rather than the numeric keypad function. See page 59 for details of SHIFT key use.

27. Example: For a system with an I_{max} value of 125 A, 0.1% of the current would be 0.125 A.
28. Example: For a system with an I_{max} value of 250 A, 0.1% of the current would be 0.250 A.

SETUP MENU

Setup of the Model 430 Programmer requires the user to navigate the setup menu. Navigation of the setup menu is intuitive — quite similar, for example, to the use of a cell phone menu.

ENTERING / EXITING SETUP MENU

To enter the setup menu, simply press the MENU key. When in any of the setup menus, pressing the MENU key will exit the setup menu. The MENU key toggles the Model 430 Programmer in and out of setup mode. Alternately, if the top level setup menu is being displayed, pressing the ESC key exits the setup menu.

MENU NAVIGATION

Pressing the MENU key enters the menu structure at the top level. The display will look approximately as shown below:

```
 0.00 A   -   Setup Mode (Select one)
+0.50 Vs  ← ▶Supply     Load    Misc →
```

The item selector (▶) points to whichever submenu was last used. The left and right arrows at the ends of the displayed submenu selections indicate that there are other submenu selections off screen, to the left and/or right of the submenu selections shown.

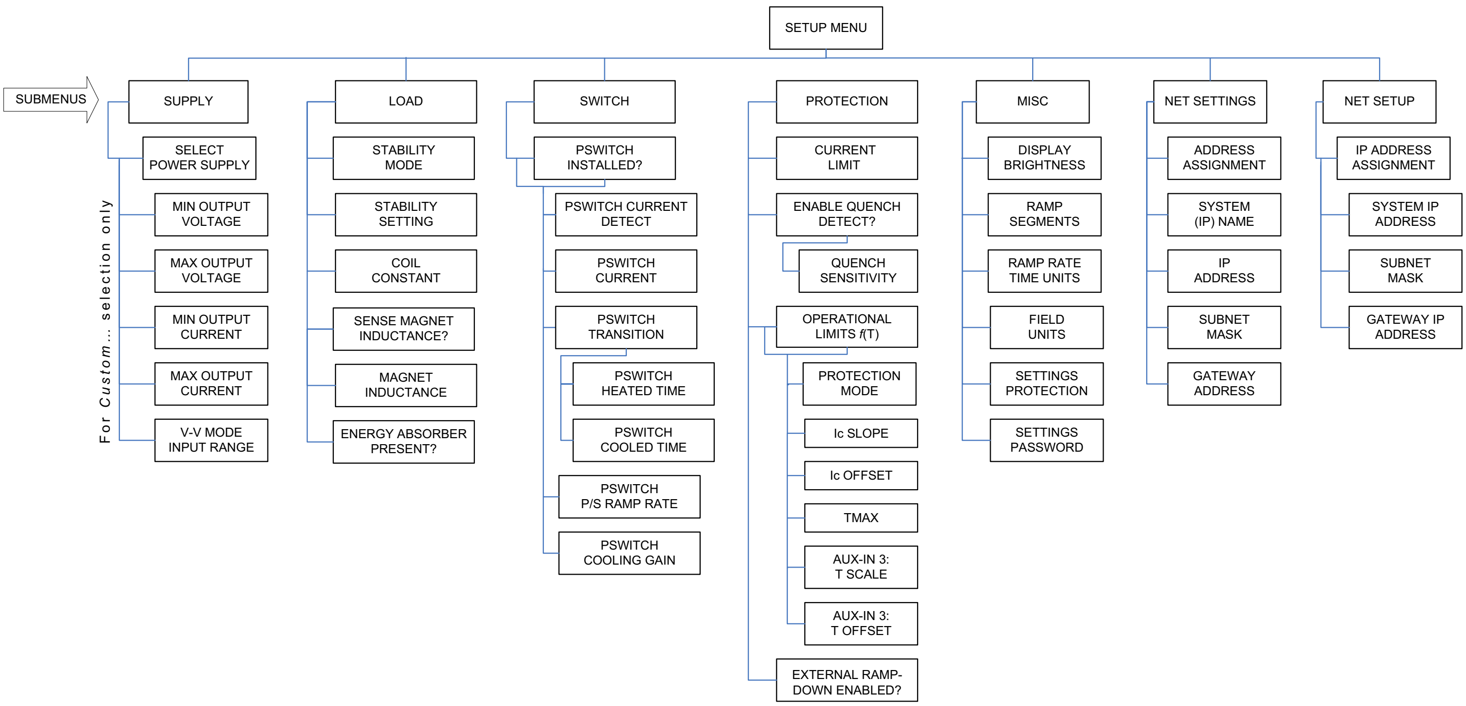
The left and right *keypad* arrows (to the left and right of the MENU key) move the item selector between the different submenu items. Pressing the left keypad arrow moves the item selector one item to the left and pressing the right keypad arrow moves the item selector one item to the right. When the last item is reached, and the right keypad arrow is pressed, the item selector will move to the first item. Likewise, when the item selector is pointing to the first item, and the left keypad arrow is pressed, the item selector will move to the last item.

Pressing the ENTER key opens the submenu to which the item selector is pointing when the ENTER key is pressed. See page 70 through page 103 for detailed descriptions of each submenu.

Pressing the ESC key exits a submenu and moves the next higher level submenu if it exists. If the top level setup menu is being displayed, pressing the ESC key exits the setup menu.

SETUP SUBMENU DESCRIPTIONS

When a submenu is entered by selecting a submenu item and pressing ENTER (see page 69 for details of menu navigation), the user will be able to edit parameters under that submenu. The Setup menu structure in summarized in the figure below:



Setup Menu Structure

The Setup submenus include: Supply, Load, Switch, Protection, Misc, Net Settings (present status), and Net Setup. Each submenu is discussed in detail in the following sections.

SUPPLY SUBMENU

The Model 430 Programmer has been configured as part of a Power Supply System. It should not be necessary to change the Supply selection. However, the Supply submenu information that follows is provided in the event that the power supply system/model must be changed.

The Supply 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[29] and the Voltage Limit[30] configuration sections.

If using a standard power supply supported by AMI, selecting a power supply within the Select Supply picklist sets all the remaining parameters in the supply submenu per the table on page 72.

NOTE **The Supply submenu is unique in that it has only the Select Supply picklist as a sublevel (unless Custom is chosen from the picklist of Select Supply options). For this reason, picklist entry is active as soon as the Supply submenu is selected; it is not necessary to first press** ENTER **to make picklist entry active in the Select Supply picklist. Also, pressing** ESC **while within the Select Supply picklist not only makes picklist entry inactive and sets the picklist selection back to where it was when the Supply submenu was selected; it also exits the Select Supply picklist.**

SELECT SUPPLY PICKLIST

```
 0.00 A   -  Select Supply*
+0.50 Vs   ←  ▶AMI 4Q06125PS→
```

The Select Supply picklist provides a set of picklist items that contain *presets for standard AMI power supplies*. The left and right keypad arrows are used to cycle through the list of selections.

When the item selector points at the desired power supply in the picklist, ENTER is pressed to select that power supply; all power supply parameters are set when the power supply model is selected. Pressing ESC while viewing the Select Supply picklist leaves the power supply selection where it was when the Supply submenu was selected, and exits the Select Supply picklist. The available Select Supply picklist values and associated power supply parameters are provided in the table on the following page.

29. See page 85.
30. See page 63.

Select Supply picklist values and associated parameters.

<table>
<tr><th>Power Supply</th><th>Min Output Voltage (V)</th><th>Max Output Voltage (V)</th><th>Min Output Current (A)</th><th>Max Output Current (A)</th><th>V-V Mode Input Range (V)</th></tr>
<tr><td>AMI 08150PS</td><td>0</td><td>+8.000</td><td>0</td><td>+150.000</td><td>0 to +10.000</td></tr>
<tr><td>AMI 12100PS</td><td rowspan="2">0</td><td rowspan="2">+12.000</td><td rowspan="2">0</td><td>+100.000</td><td rowspan="2">0 to +10.000</td></tr>
<tr><td>AMI 12200PS</td><td>+200.000</td></tr>
<tr><td>AMI 4Q05100PS</td><td>–5.000</td><td>+5.000</td><td>–100.000</td><td>+100.000</td><td rowspan="4">–10.000 to +10.000</td></tr>
<tr><td>AMI 4Q06125PS</td><td rowspan="2">-6.000</td><td rowspan="2">+6.000</td><td>-125.000</td><td>+125.000</td></tr>
<tr><td>AMI 4Q06250PS</td><td>-250.000</td><td>+250.000</td></tr>
<tr><td>AMI 4Q12125PS</td><td>-12.000</td><td>+12.000</td><td>-125.000</td><td>+125.000</td></tr>
<tr><td>AMI 10100PS</td><td rowspan="7">0</td><td rowspan="2">+10.000</td><td rowspan="7">0</td><td>+100.000</td><td rowspan="2">0 to +5.000</td></tr>
<tr><td>AMI 10200PS</td><td>+200.000</td></tr>
<tr><td>AMI 05120PS</td><td rowspan="4">+10.000[a]</td><td>+100.000</td><td rowspan="6">0 to +10.000</td></tr>
<tr><td>AMI 05240PS</td><td>+200.000</td></tr>
<tr><td>AMI 05360PS</td><td>+300.000</td></tr>
<tr><td>AMI 05600PS</td><td>+500.000</td></tr>
<tr><td>AMI 03300PS</td><td>+8.000</td><td>+300.000</td></tr>
<tr><td>HP 6260B</td><td rowspan="3">–10.000</td><td rowspan="3">+10.000</td><td>0.000</td><td>+100.000</td></tr>
<tr><td>Kepco BOP 20-5M[b]</td><td>–5.000</td><td>+5.000</td><td rowspan="2">–10.000 to +10.000</td></tr>
<tr><td>Kepco BOP 20-10M[b]</td><td>–10.000</td><td>+10.000</td></tr>
<tr><td>Xantrex XFR 7.5-140</td><td>0</td><td>+7.500</td><td>0</td><td>+140.000</td><td>0 to +10.000</td></tr>
<tr><td>Custom...[c]</td><td>–20.000</td><td>+20.000</td><td>–200.000</td><td>+200.000</td><td>–10.000 to +10.000</td></tr>
</table>

a. The individual 05100PS power supply unit will source +10.000 VDC at up to 120 A. However, the standard configuration of this series of power supplies includes the Model 601 Energy Absorber to provide bipolar operation. The 05xx0-430-601 series of power supply systems provides a maximum available voltage to the load of ±5.000 VDC at multiples of 120 or 150 A, up to 600 A depending on the system selected.

b. The Kepco BOP power supplies are used in the 4Q1005PS-430 and 4Q1010PS-430 systems are limited to only one-half the output voltage range since the supplies are designed to safely *dissipate* only one-half the rated power output.

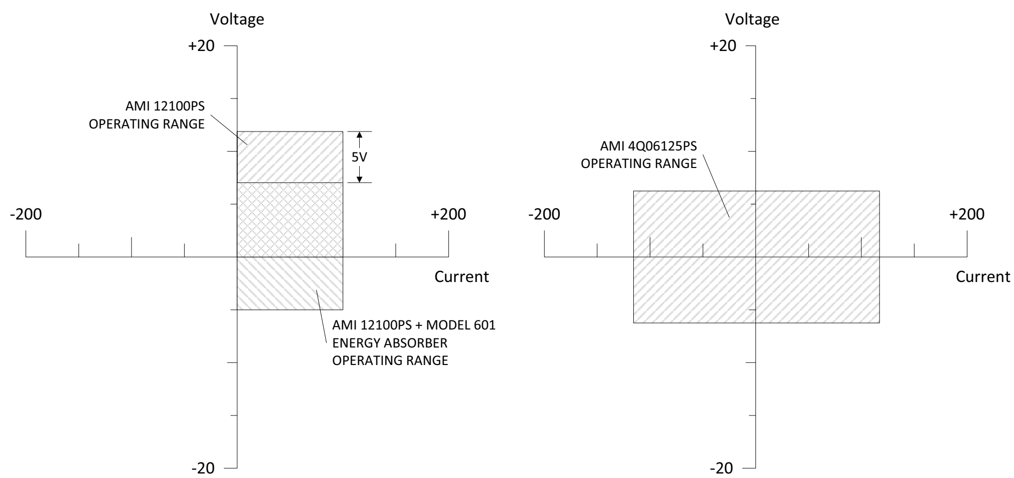
c. The values shown for the Custom... option are defaults. The user should enter the appropriate values within the respective submenus. Custom values, once entered, are saved in nonvolatile memory.

NOTE **The current must be less than 0.1% of I_{max} in order to change the Select Supply picklist value. If a change is attempted with current above this value, the Model 430 Programmer will beep and ignore the keypress. Power supply selection should also preferably be performed with the power supply off for maximum safety.**

The power supply settings define the output voltage and current ranges for a specific power supply. For example, V-I diagrams are presented in the diagram below for the AMI 12100PS and AMI 4Q06125PS selections.

The AMI 12100PS operates as a one-quadrant system without the addition of an energy absorber. As shown at left in the diagram, with the addition of an AMI Model 601 energy absorber, the AMI 12100PS system can also function as a two-quadrant supply providing +7V to -5V at the power supply system output terminals.

The AMI 4Q06125PS power supply operates as a four-quadrant power supply *without* the addition of an energy absorber as shown at right in the diagram below.



Example Power Supply Outputs

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

CUSTOM... PICKLIST ITEM

Custom... is a unique Select Supply picklist item. When selected, it opens a deeper submenu in which the custom power supply parameters (Min Output Voltage, Max Output Voltage, Min Output Current, Max Output Current and V-V Mode Input Range) are entered. Entry of each of these parameters is described below.

MIN OUTPUT VOLTAGE

```
0.00 A   -   Min Output Voltage (V)
0.00 Vs       -6.000
```

The minimum output voltage is specified in volts (V) and reflects the minimum output voltage compliance of a connected power supply. The valid range is 0.000 to -20.000 V, and can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). A *unipolar* power supply has a minimum output voltage of 0.000 V.

MAX OUTPUT VOLTAGE

```
0.00 A   -   Max Output Voltage (V)
0.00 Vs       +6.000
```

The maximum output voltage is specified in volts (V) and reflects the maximum output voltage compliance of a connected power supply. The valid range is +0.001 to +20.000 V, and can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52).

MIN OUTPUT CURRENT

```
0.00 A   -   Min Output Current (A)
0.00 Vs       +0.000
```

The minimum output current is specified in amperes (A) and reflects the minimum output current capacity of a connected power supply. The valid range is 0.000 to -100,000 A[31], and can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). A *unipolar* power supply has a minimum output current of 0.000 A.

MAX OUTPUT CURRENT

```
0.00 A   -   Max Output Current (A)
0.00 Vs       +100.000
```

The maximum output current is specified in amperes (A) and reflects the maximum output current capacity of a connected

31. The minimum and maximum output currents are also bounded by the Model 430 Programmer configuration (refer to specifications on page 17 and in the Appendix). The entered value cannot exceed the input current measurement hardware limits.

power supply. The valid range is 0.001 to +100,000 A[1], and can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52).

V-V Mode Input Range

```
 0.00 A   -   V-V Mode Input Range (V)
 0.00 Vs      ▶-10.000 to +10.000
```

The voltage-to-voltage mode input range defines the remote programming voltage input range required by the connected power supply. The remote programming voltage is the output signal provided by the Model 430 Programmer as an input to the connected power supply.

This submenu item provides a picklist of six preset selections and does not allow numeric entry of a range. The picklist values are shown in the table below.

V-V Mode Input Range Picklist Selections

+0.000 to -5.000	+0.000 to +8.000
+0.000 to +5.000	-5.000 to +5.000
+0.000 to +10.000	-10.000 to +10.000

Load Submenu

When the Load submenu is selected, several parameters associated with the superconducting magnet load can be viewed and/or changed.

Stability Mode

```
 0.00 A   -   Stability Mode
+0.50 Vs      ▶Auto    Manual    Test
```

The stability mode provides configuration of the loop control gain for operating with a magnet or testing a system on a short-circuit load. The three available selections are *Auto*, *Manual*, and *Test*.

The *Auto* stability mode automatically sets the control gain based on the configured presence or absence of a persistent switch, and the entered or measured magnet inductance value as described on page 79. A reasonably accurate guess (e.g. within 25%) or measurement must be provided for the Auto mode to function correctly.

The *Manual* stability mode provides complete control over the control gain based on a numerical entry for the stability setting. The Manual mode *requires* the operator to enter a stability setting per the description on page 76.

The *Test* stability mode is designed to allow the user to test the function of the system with *the power leads to the magnet shorted together at the magnet connection point.* This allows ramping of the system to verify proper setup. The Test mode should only be used with shorted magnet power leads for checkout purposes.

NOTE **It is important that the full length of the power leads to the magnet be connected during the *Test* mode since the leads provide some resistive load (albeit in the milliohm range) for the power supply. The output current of a truly shorted supply output (i.e. zero resistance load) is very difficult to control in voltage mode and may be unstable.**

STABILITY SETTING

```
 0.00 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 value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). The valid range is from 0.0 to 100.0%. The default value is 0.0% unless preset by AMI to match a specific superconducting magnet.

STABILITY SETTING FOR MAGNETS WITHOUT A PERSISTENT SWITCH[32]

Superconducting magnets *without* a persistent switch[33] require a specific Model 430 Programmer stability setting based on the magnet inductance as follows:

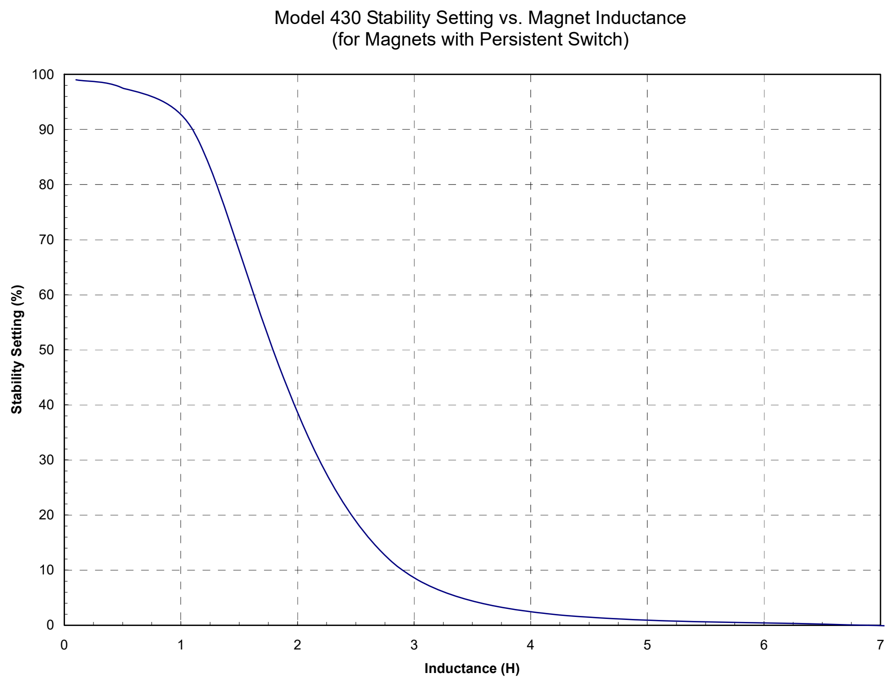
For magnet inductance $\leq$ 100 Henries (H):
Stability Setting = (100 - H)

For magnet inductance > 100 Henries:
Stability Setting = 0

32. For maximum Vm stability, you may opt to use a stabilizing resistor instead. See page 39 for details. For stabilizing resistor configurations, use the Stability Setting plot specified in the next section for magnets with a persistent switch.
33. Effective with Model 430 firmware version 1.62 or later, magnets without a switch may be operated without a stabilizing resistor present using the Stability Settings specified.

STABILITY SETTING FOR MAGNETS WITH A PERSISTENT SWITCH

The graph below may be used as a guide to set the stability setting for magnets *with a persistent switch* installed and inductance of less than 3 henries. Magnets with an inductance of greater than 3 henries that have a persistent switch installed should operate with a stability setting of 0.0%.



Stability Setting vs. Magnet (with PSwitch) Inductance

The Model 430 Programmer internal control loop gain is proportional to the multiplier (100% – [Stability Setting]). For this reason, small changes in stability setting have a large effect on stability as the value approaches 100%. Changing the stability setting from 99.9% to 99.8% changes the gain multiplier from 0.1% to 0.2% (changing the gain multiplier by a factor of 2, a 100% increase in the gain multiplier). Note, however, that the same 0.1% change in Stability Setting from 90% to 89.9% only changes the gain multiplier from 10% to 10.1% (changing the gain multiplier by a factor of 1.01, a 1% change in gain multiplier).

What this means is that if the stability setting is being adjusted to *experimentally* determine its optimum setting (using the graph above as a starting point) the recommended incremental changes for various stability setting ranges are shown in the following table.

Maximum Recommended Stability Setting Changes

Stability Setting Range	Maximum Recommended Stability Setting Change
98% to 100%	0.1%
94% to 98%	0.2%
84% to 94%	0.5%
44% to 84%	2%
0% to 44%	5%

NOTE **The Model 430 will not operate in a stable fashion on a short-circuit load unless it is configured for Test stability mode (see page 75). Otherwise the 430 control logic assumes an inductive superconducting magnet load is connected to the circuit.**

COIL CONSTANT

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

The coil constant is a scaling factor which converts the current to kilogauss (kG) or tesla (T). It is also often referred to as the *field-to-current ratio*. The coil constant is specified in kilogauss/ampere or tesla/ampere. The value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52).

Values from 0.001 to 999.99999 are acceptable for the coil constant. The default value is 1.00000 kG/A (or 0.10000 T/A) unless preset by AMI to match a specific superconducting magnet. If the coil constant value is 0.0 kG/A (or 0.0 T/A), then no conversion from amperes to kilogauss or tesla is performed — all operations will be performed and displayed in terms of amperes.

If the coil constant is not explicitly stated within a superconducting magnet's specifications, the value can be obtained by dividing the rated field by the rated current. Note that 1 T = 10 kG.

SENSE MAGNET INDUCTANCE

```
 0.00 A   -   Sense Magnet Inductance?
 0.00 Vs     ▶Calculate (start w/ENTER)
```

This menu pick will start a process to measure the inductance of the load magnet. The inductance is determined by measuring the voltage developed across the magnet (V_m) with a fixed *di/dt* (current rate-of-change in A/sec) passed through the load. *The function must be executed with the magnet ramping.*[34] When the sense is initiated by pressing the ENTER key, the algorithm will wait for 2 seconds to allow the charge rate to stabilize and then make voltage and current measurements, calculate the inductance, and display the result.

```
+46.19 A  ↑  Sense Magnet Inductance?
 +0.50 Vs          32.13 H
```

The sensed magnet inductance is automatically saved as the present magnet inductance and is immediately used to adjust the control gains if the Model 430 is configured for Auto stability mode (see page 75).

If the magnet is persistent, not ramping, or encounters a ramp rate change during the measurement, the measurement will be aborted with a displayed error notification, and any existing magnet inductance value is retained.

MAGNET INDUCTANCE

```
 0.00 A   -   Magnet Inductance (H)
+0.50 Vs        32.13
```

The magnet inductance submenu displays the present inductance value for the magnet load and allows manual entry of a new value or initial guess (an initial guess within ~25% is adequate). The magnet inductance value *is saved* between power cycles.

The magnet inductance value, when entered, is immediately used for control gain configuration if the Model 430 is set for Auto stability mode (see page 75).

34. See page 108.

NOTE **If connecting a different magnet load, please ensure that the magnet inductance is set with a known value or an initial guess in order to ensure proper operation.**

ENERGY ABSORBER PRESENT

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

This picklist value indicates whether an energy absorber, such as the AMI Model 601, is connected to the power supply system. The default setting is *NO*.

It is important for this setting to be correct since the control gain tables of the Model 430 Programmer compensate for the additional load of the energy absorber if present. The increased gain when an energy absorber is present will also decrease (but not eliminate) the time required for the system to “forward bias” the energy absorber.[35]

SWITCH SUBMENU

The Switch submenu provides a top menu for indicating if a persistent switch is installed on the presently connected magnet load, and, if so, several submenus for configuring the various operating parameters for the switch.

PSWITCH INSTALLED

```
  0.00 A   -   PSwitch Installed?
  0.00 Vm       NO     ▶YES
```

This picklist value indicates whether or not a persistent switch is installed.

If *YES* is selected, the PSwitch Current Detect, PSwitch Current, PSwitch Transition, PSwitch Heated Time, PSwitch Cooled Time, PSw P/S Ramp Rate, and PSwitch Cooling Gain settings are made available within the Switch submenu.

35. The Model 430 Programmer will bring the output voltage of the power supply to the point where the energy absorber can provide current to the magnet.

If *NO* is selected, the various settings are *not* made available within the Switch submenu and the PERSIST. SWITCH CONTROL key becomes inoperable.

The default value is *YES* unless preset by AMI to match a specific superconducting magnet.

PSWITCH CURRENT DETECT (MA)

```
0.00 A   P  PSwitch Current Detect(mA)
0.00 Vm     ▶Auto detect
```

This function will automatically determine the proper value of heater current in a persistent switch installed on a magnet connected to the power supply system. The power supply should be energized and at zero current. When the ENTER key is pressed to initiate the process, the following steps occur:

1. The persistent switch current is set to 0.1 mA.
2. The power supply current is ramped to 2 A at 0.1 A/sec.
3. After the power supply current reaches 2 A, the persistent switch current is slowly increased (as shown on the display) until the Model 430 Programmer detects a change in the load, indicative of the persistent switch transitioning from superconducting to resistive. Before this transition is detected, the display will show the heater current value as it is increased in the persistent switch heater; the magnet current is changed back to zero during this process.

```
+2.00 A   P  PSwitch Current Detect(mA)
+0.37 Vm     Detecting...(26.7mA)
```

4. The current that was present when the superconducting to resistive transition occurred is displayed.

```
0.00 A   P  PSwitch Current Detect(mA)
0.00 Vm     ▶ 27.2
```

NOTE **If the PSwitch Current determined by this method is accepted as described below, the detection process will exit to the heated switch mode with <u>zero amps</u> being delivered to the magnet.**

5. If the ENTER key is pressed, the determined value of PSw current is stored in the Model 430 Programmer. If the escape key is pressed,

the value determined in step 4 above is discarded and the previously set persistent switch current is retained.

PSwitch Current

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

The persistent switch heater current can be manually set to any value between 0.0 and 125.0 mA. The value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). The default value is 10.0 mA unless preset by AMI to match a specific superconducting magnet.

PSwitch Transition

```
+50.00 A   -  PSwitch Transition
 +0.50 Vs     ▶Timer      Magnet Voltage
```

The persistent switch transition (from heated-to-cooled and vice-versa) can be detected by one of two methods: timer-based or by direct sensing of the magnet voltage.

The timer-based method is the default and simply uses heated and cooled state timers as entered by the operator in the PSwitch Heated Time and PSwitch Cooled Time settings.

Optionally, the operator can choose to use the magnet voltage method. This method works by directly sensing the running mean and variance of the magnet voltage and comparing them to preset limits. This method has the advantage of typically requiring much less time to sense the transition of the persistent switch from the heated to cooled state.

NOTE **In order to use the magnet voltage switch transition detection, higher resolution of the magnet voltage measurement is necessary. This is achieved by connecting the magnet voltage to Auxiliary Input 1, which has a ±1.0 VDC input range with 20 times more resolution (~0.5 mV/bit) than the standard magnet voltage input.**

Model 430 units that ship with version 3.00 or later firmware installed have internally connected the magnet voltage input from the Magnet Station connector to the Auxiliary Input 1 (therefore, the Auxiliary Input 1 is consumed and is not available for general use). For older, already fielded units the user will be required to install an external jumper cable from one of the Magnet Station connectors to the Auxiliary Input 1 to use the magnet voltage based switch transition feature. See page 200 for more details.

NOTE **The magnet voltage method of sensing persistent switch transitions *requires* the magnet voltage input to the rear panel Magnet Station connector as described on page 191. Please note that some magnet system manufacturers do not provide magnet voltage taps.**

PSwitch Heated Time

```
+50.00 A   -   PSwitch Heated Time (sec)
 +0.50 Vs         20
```

The persistent switch heated time is only displayed for, and applies only to, the timer-based switch transition method and is the amount of time required for the persistent switch to heat completely and become fully normal (resistive). The time may be set to any value between 5 and 120 seconds[36]. The value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). The default is 20 seconds unless preset by AMI to match a specific superconducting magnet.

During the persistent switch heating period, the Model 430 Programmer ramping functions are disabled. The time delay is necessary to ensure that the Model 430 will not switch to the higher control gain required for proper magnet operation before the magnet is actually available in the circuit (not being shunted by the persistent switch). If magnet operation is not stable after expiration of the heating period, increase the heated time to allow more time for the switch to heat. The default value of 20 seconds is adequate for the majority of wet and dry persistent switches.

PSwitch Cooled Time

```
+50.00 A   -   PSwitch Cooled Time (sec)
 +0.50 Vs         20
```

The PSwitch Cooled Time is only displayed for, and applies only to, the timer-based switch transition method and is the amount of

36. During the heating cycle, a “countdown” will be displayed indicating the number of seconds remaining in the cycle.

time required for the persistent switch to cool completely and become fully superconducting. The time may be set to any value between 5 and 3600 seconds[37]. The value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). The default is 20 seconds unless preset by AMI to match a specific superconducting magnet.

During the persistent switch cooling period, the Model 430 Programmer ramping functions are disabled. The default value of 20 seconds is adequate for many wet persistent switches. Persistent switches on conduction cooled magnets (dry switches) will require significantly longer cooling times than wet switches.

For dry switches, the operator may want to consider the optional magnet voltage switch transition detection method if magnet voltage taps are available and connected to the Model 430 Programmer.

PSWITCH POWER SUPPLY RAMP RATE

```
+50.00 A   -   PSw P/S Ramp Rate (A/sec)
 +0.50 Vs        10
```

The persistent switch power supply ramp rate is the rate at which the magnet power supply will automatically be ramped up or down while an installed persistent switch is in the cooled state. The rate may be set to any value between 0.1 and 10 A/sec.

The purpose of this parameter is to reduce the amount of time the system requires to either match an existing persistent magnet current, or to reach zero current for powering off a system with the magnet in a persistent state. This ramp rate can be set much higher than the rate required while charging/discharging the magnet (note that a *persistent* magnet is not in-circuit). In fact, the typical practice is to set this parameter to its maximum value.

The value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52). The default is 10 A/sec unless preset by AMI to match a specific superconducting magnet system.

37. During the cooling cycle, a “countdown” will be displayed indicating the number of seconds remaining in the cycle.

PSwitch Cooling Gain

```
0.00 A  P  PSwitch Cooling Gain (%)
0.00 Vs      0.0
```

The default cooling gain of 0.0% may be adequate for the majority of wet persistent switches. However, this setting can offset magnet field/current drift during persistent switch cooling, especially with conduction cooled switches which generally require longer cooling times.

Increasing the cooling gain adds control loop gain during the switch cooling cycle. Too little cooling gain may result in magnet drift during a long period of switch cooling. Most systems that require some cooling gain to control magnet drift will likely work with value set to about 25%. The value can be set by using either the numeric keypad as described on page 51 or the fine adjust knob (on page 52).

Protection Submenu

The Protection submenu configures parameters related to protective measures that can be applied to magnet operation to prevent accidental damage and respond during a quench or other critical events.

Current Limit

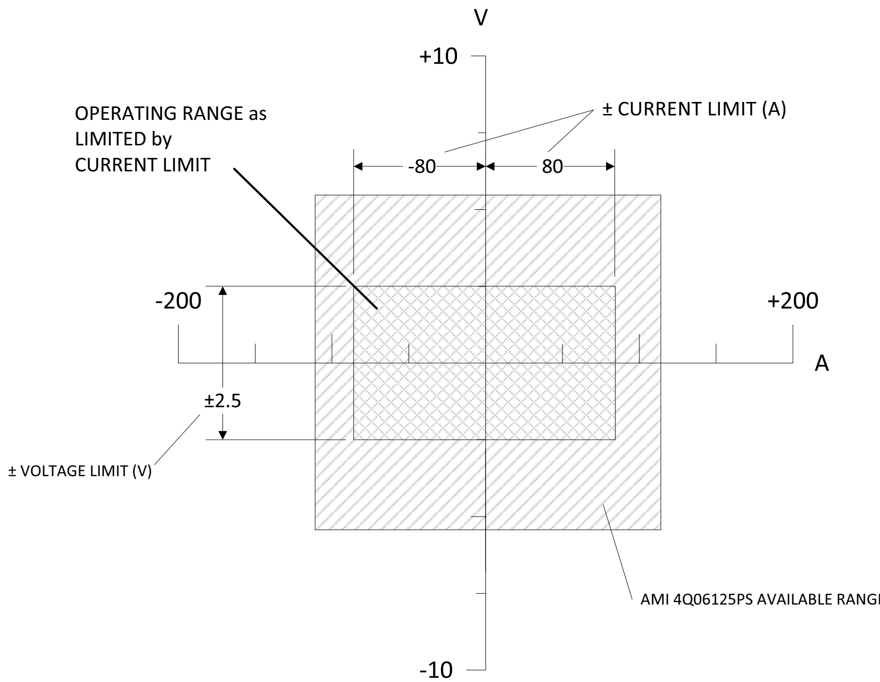
```
0.00 A  P   Current Limit (A)
0.00 Vm      ±100.000
```

CAUTION **The Current Limit is normally set to the Magnet Rated Current specific to the connected superconducting magnet. The setting should not be changed unless a different magnet is to be used; always refer to the magnet specifications (see page 105) before changing the Current Limit.**

A magnet operates within the capabilities of the associated power supply. The current output limits of the supply, which are not user-adjustable, should be selected to be equal to or higher than the Current Limit.

If the power supply is four-quadrant, the Current Limit applies to both the positive and the negative current direction (current limit symmetry).

The Current Limit is normally preset by AMI to match a specified superconducting magnet. If AMI is not supplying the magnet of if the specific magnet data has not been provided by the customer, the Model 430 will ship with the Current Limit set at the default value of ±80 A. The figure on the following page shows the default Current Limit (±80 A) and a Voltage Limit (±2.5 V) as a sub-range within the 4Q06125PS power supply output limits.



Current and Voltage Limits set within the Supply Ranges

The Current Limit can be set by using either the numeric keypad as describe on page 51 or the fine adjust knob (on page 52). The Model 430 Programmer will beep once, indicate an error, and deny the change if the user attempts to set the Current Limit below the present Target Field Setpoint or above the maximum output current of the selected power supply.

ENABLE QUENCH DETECT

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

The internal quench detection function of the Model 430 Programmer may be enabled or disabled according to the preference of the user. The default value is NO.

A user input for *external quench detection* is also provided on the rear panel of the Model 430 Programmer[38]. The external input overrides the internal quench detection function of the Model 430 and cannot be disabled. For further discussion of the quench detection logic and operation, please refer to on page 120.

ADDITIONAL QUENCH DETECTION SELECTIONS

If the optional *Operational Limits f(T)* functionality is enabled (see page 88), then the quench detection menu includes some additional selections as illustrated below:

```
+50.00 A   -   Enable Quench Detect?
 +0.50 Vs       Off  ▶Current  Tmax  Both
```

As described previously, the quench detect can be set to *Off* and is inactive. If set to *Current*, the detection is based on magnet current only which is the same as the base quench detection functionality as described above.

If set to *Tmax*, the detection logic will only be based on the input temperature from an external measurement device that is connected to Auxiliary Input 3 on the rear panel of the Model 430 (see page 200).

If set to *Both*, the quench detection logic will operate on both the magnet current *and* the temperature measurement provided via Auxiliary Input 3. If either violates the predefined detection logic, a quench will be detected.

QUENCH SENSITIVITY

```
+50.00 A   P   Quench Sensitivity (Rate)
 +0.50 Vs       Less  <  ▶Normal   >  More
```

This picklist value specifies the sensitivity (formerly called “rate”) of the quench detection algorithm. The default “Normal” value will be appropriate for most magnets. Occasionally, some magnets quench very slowly and the value of this parameter may need to be adjusted to a more sensitive value so that the Model 430 Programmer detects the gradual, slow quench.

The available range for this parameter is five (5) steps from least to most sensitivity. If the magnet quenches and the Model 430 Programmer does not detect the quench, the sensitivity should

38. Refer to page 198.

be increased (i.e. More sensitivity) until all quenches are detected.

OPERATIONAL LIMITS[39]

```
+50.00 A   -  Operational Limits f(T)
 +0.50 Vs     ▶Edit Constants
```

This heads a menu subsection containing various constants associated with protection based on a linear relationship for a maximum allowable current, termed as ***Ic***, given a temperature measured via the Auxiliary Input 3 (see page 200). Press the ENTER key to access the associated submenu parameters.

The equations that relate the parameters in this subsection are defined as:

$$\text{If } T \le T_{max} \Rightarrow \quad \boldsymbol{Ic} = (IcSlope)T + (IcOffset)$$
$$\text{If } T > T_{max} \Rightarrow \quad \boldsymbol{Ic} = 0$$

where ***Ic*** is in Amperes, *IcSlope* is Amperes/Kelvin, *T* is the Auxiliary Input channel 3 temperature in Kelvin, *IcOffset* is in Amperes, and T_{max} is in Kelvin. The ***Ic*** limit is applied in a bipolar fashion, i.e. it is applied to the magnet current *magnitude*.

The equations above define an operating region that is illustrated in the “Ic vs. Tempeature” plot at the top of the following page, with example parameter values of -22 A/K for *IcSlope*, 180 A for *IcOffset*, and 5.5 K for T_{max}. **The valid operational region is along and to the left of the line**.

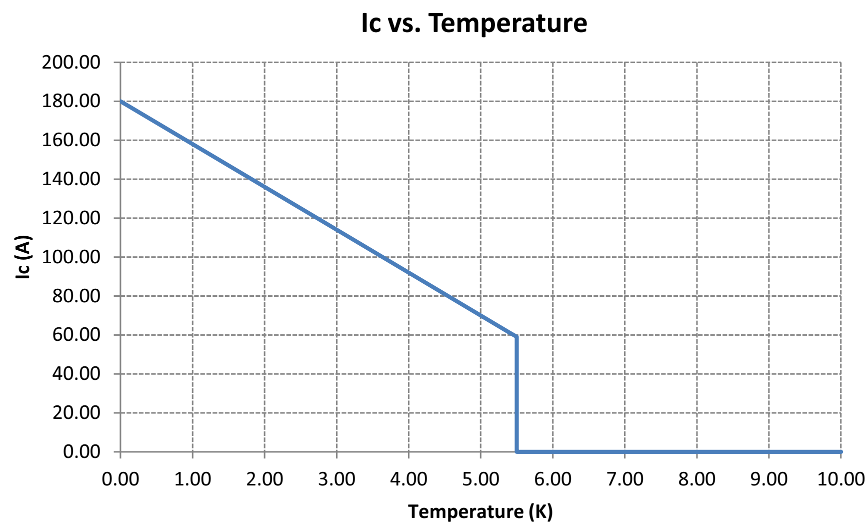
PROTECTION MODE

```
+50.00 A   -  Protection Mode
 +0.50 Vs     ▶Off   On Entry   Cont f(T)
```

This setting controls how the maximum current protection is applied. If the Protection Mode setting is *Off*, then no additional protection is applied.[40]

39. The Operational Limits menu can be hidden with an internal hardware switch. If this menu is not visible, then the hardware switch has been set to hide it. Contact an Authorized AMI Technical Support Representative if you wish to enable this feature.

40. The Tmax parameter may still be used as part of the quench detection logic, see page 120.



Example of *Ic* (i.e. critical current) vs. Temperature protection line

If the Protection Mode setting is *On Entry*, the Target Field Setpoint is checked *only during a new entry* against the presently calculated value of ***Ic*** and the new entry must be less than or equal to ***Ic***. The Model 430 Programmer will beep once, indicate an error, and deny the new entry to the Target Field/Current Setpoint if the value exceeds ***Ic***.

If the Protection Mode setting is *Cont f(T)*, representing the continuous function of temperature, the Target Field Setpoint entry protection is applied *and* the operating current of the magnet is continuously checked against the calculated value of ***Ic*** based on the present temperature measured via the Auxiliary Input channel 3. This mode actively limits the magnet current to less than or equal to ***Ic***.

If the temperature increases during operation and the present magnet current then exceeds ***Ic***, the magnet is automatically ramped down in current magnitude to satisfy the ***Ic*** limit at the specified system ramp rate (this includes ramping the magnet to zero field/current if the present temperature exceeds T_{max}). If attempting to ramp the magnet current above ***Ic***, the magnet current is held at the value of ***Ic***. Either limited condition is indicated by an inverse video T character in the status indicator display which indicates the "Temperature Limited" state.

If the Protection Mode is "Off", the present temperature measured via Auxiliary Input channel 3 can be displayed in the default display by pressing the right or left arrow keys. If the Protection Mode is "On Entry" or "Cont f(T)" both the real-time calculated value of ***Ic*** *and* the current temperature are displayed.

Ic is always displayed in Amperes. This default display option is illustrated below along with an illustration of the status indicator indicating a temperature-limited condition (i.e. the reverse-video T character):

```
+50.53 A  T  Mode: Ramping: Ic=50.5
  4.50 K     No PSwitch Installed
```

Illustration of optional default display showing the value of *Ic*, the present Aux-In 3 temperature, and a temperature-limited condition.

To remove the ***Ic*** and/or temperature display, simply press the left or right arrow key again.

IC SLOPE

```
+50.00 A  -  Ic Slope (A/K)
 +0.50 Vs      -22.000
```

This value sets the *Ic Slope* parameter in Amperes/Kelvin. Note that for superconducting magnets, the slope value will be negative since the maximum current density increases with decreasing temperature.

IC OFFSET

```
+50.00 A  -  Ic Offset (A)
 +0.50 Vs      +150.000
```

This value sets the *Ic Offset* parameter in Amperes. This value shifts the entire ***Ic*** line by a current offset. A higher offset value will increase the value of ***Ic*** for a given temperature.

TMAX

```
+50.00 A  -  Tmax (K)
  4.50 K       6.000
```

This value is a maximum allowable system temperature as measured via the Auxiliary Input channel 3 in Kelvin. The Model 430 Programmer will limit entry of the Target Field/Current Setpoint to a value of zero if the present temperature exceeds T_{max}. If the Protection Mode is set for “Cont f(T)”, then *the* *magnet will also be ramped to zero field/current* if the temperature exceeds T_{max}.

Aux-In 3: T Scale

```
+50.00 A  -  Aux-In 3: T Scale (K/V)
  4.50 K       +1.000
```

This value controls the scaling of the voltage measured via the Auxiliary Input channel 3 (see page 200). The measured voltage is multipled by this scale factor in Kelvin/Volts. The value is determined by the specific output scaling applied by the external temperature measurement device.

NOTE **The correctness of this scaling parameter is critical to the accurate operation of the protection afforded by the Operational Limits function.**

Aux-In 3: T Offset

```
+50.00 A  -  Aux-In 3: T Offset (K)
  4.50 K        0.000
```

This value controls the offset in Kelvin of the temperature measured via the Auxiliary Input channel 3 (see page 200). The measured voltage is first multipled by the *T Scale* factor and then the *T Offset* is added to determine the voltage-to-temperature conversion. The value is determined by the specific output offset applied by the external temperature measurement device.

NOTE **The correctness of this offset parameter is critical to the accurate operation of the protection afforded by the Operational Limits function.**

Enable External Rampdown

```
  0.00 A  -  External Rampdown Enabled?
  0.00 Vs    ▶NO       YES
```

The External Rampdown function of the Model 430 Programmer can be used to allow an external contact-signal to cause the magnet to be ramped to zero field (even if it is in persistent mode) should a fault or alarm occur in a magnet system. Signals such as low liquid levels, cryocooler compressor faults, or abnormal temperatures can be used to trigger a controlled magnet rampdown, even if the magnet is in persistent mode. See page 198.

The external rampdown function may be enabled or disabled according to the preference of the user. The default value is NO. With the exception of enable control, the settings and parameters for the external rampdown function can be edited *only* via the remote interface (see page 171).

A user input for initiating an *external rampdown* is provided on the rear panel of the Model 430 Programmer[41]. For further discussion of the quench detection logic and operation, please refer to on page 122.

MISC SUBMENU

When the Misc submenu is selected, several miscellaneous parameters may be viewed and/or changed.

DISPLAY BRIGHTNESS

```
+50.00 A   -   Display Brightness (%)
 +0.50 Vs       25     50     75    ▶100
```

This picklist value controls display brightness. As shown above, there are four brightness settings from which to choose (25%, 50%, 75% and 100%). The default setting is 100%.

RAMP SEGMENTS

```
+50.00 A   -   Ramp Segments (1-10)
 +0.50 Vs        1
```

The ramp segments value specifies the number of current ranges which can be given unique ramp rate values. The default value is 1 unless preset by AMI to match a specific superconducting magnet.

When this value is 1, there is only one ramp rate for the Model 430 Programmer, used for the full available current range. For multiple ramp rates, set the value to the number of ramp segments desired (up to ten segments). See page 60 for details regarding the use of ramp rate segments.

41. Refer to page 198.

RAMP RATE TIME UNITS

```
+50.00 A   -  Ramp Rate Time Units
 +0.50 Vs     ▶Seconds     Minutes
```

This picklist value specifies the unit of time used to enter and the display ramp rate. If Seconds is selected, ramp rate is entered in A/s, kG/s or T/s; if Minutes is selected, ramp rate is entered in A/min, kG/min or T/min. The selected unit value also applies to remote interface commands. The default setting is Seconds.

FIELD UNITS

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

This picklist value specifies whether the field is specified and displayed in units of kilogauss (kG) or tesla (T). The units selected also applies to remote interface commands. The default setting is kilogauss.

SETTINGS PROTECTION

```
+50.00 A   -  Settings Protection
 +0.50 Vs     ▶Edit Settings
```

Settings Protection allows virtually[42] every command and menu/submenu setting to be protected from alteration or use. If a setting is locked, it cannot be used from the front panel without first unlocking the setting, which requires entering the correct password. Note that settings protection only applies to front panel access, and not to remote access (via Ethernet or RS-232).

The use of settings protection allows specific commands and/or settings to be locked by a magnet system "administrator," so that the general user cannot execute those commands and/or modify those settings. The implementation of settings protection in the Model 430 Programmer is very flexible; it allows as many or as few commands and/or settings to be locked as the magnet system administrator desires. The magnet system administrator may lock all but a few commands/settings, so that, for instance,

42. The one exception is the RAMP TO ZERO button which cannot be locked. Also, Magnet Inductance and Net Settings are not subject to locking due to their "read-only" nature.

the general user has access to only the RAMP / PAUSE and RAMP TO ZERO keys. Conversely, the administrator may lock, for instance, only the Current Limit setting from use by the general user.

If an attempt is made to use a locked command or setting, the Model 430 Programmer beeps twice; the command is not accepted and the setting is not altered.

When ENTER is pressed to change settings protection, the password must be correctly entered before settings protection can be edited.

```
+50.00 A   -   Enter Password*
 +0.50 Vs        _
```

Using the keypad, type the numeric password (up to 4-digits) and press ENTER. The default password is 1234. If an incorrect password is entered, the Model 430 Programmer beeps and again prompts for the password. Once the password has been correctly entered, the protection value (Locked or Unlocked) can be edited for each setting. The default protection value for all settings is Unlocked.

NOTE **Once the password has been correctly entered, if no keys are pressed for one minute, the Settings Protection submenu will be exited, and the password must be entered again if further changes to settings protection are desired.**

If the correct password has been forgotten, contact AMI Technical Support for assistance. To change the password, see page 100.

PSWITCH CONTROL LOCK

```
+50.00 A   -   PSwitch Control Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the PERSIST. SWITCH CONTROL key is locked or unlocked. The default value is Unlocked.

TARGET FIELD SETPT LOCK

```
+50.00 A   -   Target Field Setpt Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the TARGET FIELD SETPOINT key is locked or unlocked. The default value is Unlocked.

RAMP / PAUSE LOCK

```
+50.00 A   -   Ramp / Pause Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the RAMP / PAUSE key is locked or unlocked. The default value is Unlocked.

RAMP TO ZERO LOCK

```
+50.00 A   -   Ramp To Zero Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the RAMP TO ZERO key is locked or unlocked. The default value is Unlocked.

RAMP RATE SETTINGS LOCK

```
+50.00 A   -   Ramp Rate Settings Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether ramp rate settings are locked or unlocked. Ramp rate settings protected by this setting are: use of the RAMP RATE key menu, editing of the Ramp Segments value (under the Misc submenu) and editing of the Ramp Time Units value (under the Misc submenu). The default value is Unlocked.

POWER SUPPLY LOCK

```
+50.00 A   -   Power Supply Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether the Select Supply picklist value is locked or unlocked. If the Select Supply value is

Custom..., then setting Power Supply Lock to Locked also prevents the custom power supply parameters (Min Output Voltage, Max Output Voltage, Min Output Current, Max Output Current and V-V Mode Input Range) from being edited. The default value is Unlocked.

VOLTAGE LIMIT LOCK

```
+50.00 A   -   Voltage Limit Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the VOLTAGE LIMIT SHIFT-key menu is locked or unlocked. The default value is Unlocked.

RESET QUENCH LOCK

```
+50.00 A   -   Reset Quench Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the RESET QUENCH SHIFT-key command is locked or unlocked. The default value is Unlocked.

INCR./DECR. FIELD LOCK

```
+50.00 A   -   Incr./Decr. Field Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the INCR. FIELD and DECR. FIELD SHIFT-key commands is locked or unlocked. The default value is Unlocked.

FIELD <> CURRENT LOCK

```
+50.00 A   -   Field <> Current Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the FIELD <> CURRENT SHIFT-key command is locked or unlocked. The default value is Unlocked.

FIELD UNITS LOCK

```
+50.00 A  -  Field Units Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the Field Units value is locked or unlocked (whether accessed through the FIELD UNITS key menu or under the Misc submenu). The default value is Unlocked.

STABILITY SETTING LOCK

```
+50.00 A  -  Stability Setting Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the Stability Mode and Stability Setting values are locked or unlocked (whether accessed through the STAB. key menu or under the Load submenu). The default value is Unlocked.

INDUCTANCE LOCK

```
+50.00 A  -  Inductance Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the Sense Magnet Inductance function and Magnet Inductance value are locked or unlocked (under the Load submenu). The default value is Unlocked.

VS <> VM LOCK

```
+50.00 A  -  Vs <> Vm Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether use of the Vs <> Vm SHIFT-key command is locked or unlocked. The default value is Unlocked.

VOLT METER LOCK

```
+50.00 A   -   Volt Meter Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the VOLT METER SHIFT-key command is locked or unlocked. The default value is Unlocked.

FINE ADJUST LOCK

```
+50.00 A   -   Fine Adjust Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether use of the FINE ADJUST SHIFT-key command is locked or unlocked. The default value is Unlocked.

COIL CONSTANT LOCK

```
+50.00 A   -   Coil Constant Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether the Coil Constant value (under the Load submenu) is locked or unlocked. The default value is Unlocked.

CURRENT LIMIT LOCK

```
+50.00 A   -   Current Limit Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether the Current Limit value (under the Load submenu) is locked or unlocked. The default value is Unlocked.

PSWITCH SETTINGS LOCK

```
+50.00 A   -   PSwitch Settings Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether persistent switch settings are locked or unlocked. Persistent switch settings protected by this setting (all under the Switch submenu) are: PSwitch Installed picklist value, PSwitch Current Detect, PSwitch Current value, PSwitch Transition picklist value, PSwitch Heated Time value, PSwitch Cooled Time value, PSwitch P/S Ramp Rate value, and the PSwitch P/S Cooling Gain value. The default value is Unlocked.

QUENCH DETECT LOCK

```
+50.00 A  -  Quench Detect Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the Enable Quench Detect picklist value (under the Protection submenu) is locked or unlocked. The default value is Unlocked.

QUENCH SENSITIVITY LOCK

```
+50.00 A  -  Quench Sensitivity Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the Quench Sensitivity picklist value (under the Protection submenu) is locked or unlocked. The default value is Unlocked.

ABSORBER PRESENT LOCK

```
+50.00 A  -  Absorber Present Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the Energy Absorber Present picklist value (under the Load submenu) is locked or unlocked. The default value is Unlocked.

EXTERNAL RAMPDOWN LOCK

```
 +0.00 A  -  External Rampdown Lock
 +0.50 Vs     Locked      ▶Unlocked
```

This picklist value specifies whether the external rampdown function (under the Protection submenu) is locked or unlocked. The default value is Unlocked.

DISPLAY BRIGHTNESS LOCK

```
+50.00 A   -   Display Brightness Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether the Display Brightness picklist value (under the Misc submenu) is locked or unlocked. The default value is Unlocked.

NET SETUP LOCK

```
+50.00 A   -   Net Setup Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether the Net Setup submenu is locked or unlocked. The default value is Unlocked.

OPERATIONAL LIMITS LOCK

```
+50.00 A   -   Operational Limits Lock
 +0.50 Vs       Locked      ▶Unlocked
```

This picklist value specifies whether the Operational Limits (that are a function of input temperature) submenus are locked or unlocked (under the Protection submenu). The default value is Unlocked.

SETTINGS PASSWORD

```
+50.00 A   -   Settings Password
 +0.50 Vs      ▶Change Password
```

Settings Password is a password protected submenu under the Misc submenu. It provides a means of changing the settings protection password.

When ENTER is pressed to change the settings protection password, the current password must be correctly entered before a new password can be entered.

```
+50.00 A   -   Enter Current Password*
 +0.50 Vs       _
```

Using the keypad, type the current 4-digit (maximum) numeric password and press ENTER. The default password is 1234. If an incorrect password is entered, the Model 430 Programmer beeps and again prompts for the password. Once the password has been correctly entered, the user is prompted for the new password.

```
+50.00 A   -   Enter New Password*
 +0.50 Vs        _
```

Using the keypad, type the new 4-digit (maximum) numeric password and press ENTER. The user is then prompted to re-enter the new password for confirmation.

```
+50.00 A   -   Enter New Password Again*
 +0.50 Vs        _
```

Using the keypad, again type the new 4-digit (maximum) numeric password and press ENTER. If the second password entry does not match the first password entry, the Model 430 Programmer beeps and the user is prompted again to re-enter the new password. The new password is not accepted until it is confirmed by entering the same password a second time. If ESC is pressed before confirmation is completed, the display returns to the Settings Password submenu, and the current password remains unchanged.

NET SETTINGS SUBMENU

Selecting the Net Settings submenu allows all currently assigned network settings to be *viewed* (but not edited). To *edit* network settings, select the Net Setup submenu.

ADDR ASSIGNMENT (PRESENT)

```
+50.00 A   -   Addr Assignment (Present)
 +0.50 Vs      DHCP
```

This submenu item displays the currently selected method of IP address assignment. The value will either be DHCP or Static. The default value is DHCP, which means that the system IP address, the subnet mask and the gateway IP address are dynamically determined by the network DHCP server.

SYSTEM NAME (PRESENT)

```
+50.00 A   -   System Name (Present)
 +0.50 Vs      AMI
```

This submenu item displays the currently assigned system name (also known as *host name* or *computer name*), the *name* by which the Model 430 Programmer is identified on a network. This setting can *only* be modified using remote communications (either Ethernet or RS-232); it cannot be edited using the front panel keypad.

IP ADDRESS (PRESENT)

```
+50.00 A   -   IP Address (Present)
 +0.50 Vs      0.0.0.0 (DHCP)
```

This submenu item displays the currently assigned system IP address for the Model 430 Programmer. The value in parentheses after the IP address value indicates how the IP address is assigned. DHCP indicates that the value is dynamically assigned by a DHCP server; Static indicates that the value is static, assigned by the Model 430 user. The default value is 0.0.0.0. However, since the default method of IP address assignment is by DHCP server, this value is typically set by the network DHCP server.

SUBNET MASK (PRESENT)

```
+50.00 A   -   Subnet Mask (Present)
 +0.50 Vs      0.0.0.0 (DHCP)
```

This submenu item displays the currently assigned subnet mask for the Model 430 Programmer. The value in parentheses after the subnet mask value indicates how the subnet mask is assigned. DHCP indicates that the value is dynamically assigned by a DHCP server; Static indicates that the value is static, assigned by the Model 430 user. The default value is 0.0.0.0. However, since the default method of subnet mask assignment is by DHCP server, this value is typically set by the network DHCP server.

GATEWAY ADDRESS (PRESENT)

```
+50.00 A  -  Gateway Address (Present)
 +0.50 Vs    0.0.0.0 (DHCP)
```

This submenu item displays the currently assigned gateway IP address for the Model 430 Programmer. The value in parentheses after the gateway IP address value indicates how the gateway IP address is assigned. DHCP indicates that the value is dynamically assigned by a DHCP server; Static indicates that the value is static, assigned by the Model 430 user. The default value is 0.0.0.0. However, since the default method of subnet mask assignment is by DHCP server, this value is typically set by the network DHCP server.

NET SETUP SUBMENU

Selecting the Net Setup submenu allows network settings to be *edited* (except for the system name, which can only be modified using remote communications). Note also that the system IP address, the subnet mask and the gateway IP address can only be assigned by the user if the currently selected method of IP address assignment is Static; if the currently selected method of IP address assignment is DHCP, then these three values will be set by the network DHCP server.

IP ADDRESS ASSIGNMENT

```
+50.00 A  -  IP Address Assignment
 +0.50 Vs    ▶DHCP    Static
```

This picklist value specifies method of IP address assignment. The value can be set to either DHCP or Static. If the value is DHCP, then the system IP address, the subnet mask and the gateway IP address are dynamically assigned by the network DHCP server. If the value is Static, then the system IP address, the subnet mask and the gateway IP address are assigned static values by the user. The default value is DHCP.

NOTE **If the IP Address Assignment value is changed, the Model 430 Programmer power _must_ be cycled off for at least 15 seconds and then back on to complete the change. The previous value will continue to be used until the Model 430 is restarted.**

System IP Address

```
+50.00 A   -   System IP Address
 +0.50 Vs      0.0.0.0
```

If IP Address Assignment is Static, then the system IP address can be assigned by the user. The default value is 0.0.0.0.

NOTE **This item is only available in the Net Setup submenu if IP Address Assignment is Static. If IP Address Assignment is DHCP, the system IP address is assigned by the network DHCP server and cannot be assigned by the user.**

Subnet Mask

```
+50.00 A   -   Subnet Mask
 +0.50 Vs      0.0.0.0
```

If IP Address Assignment is Static, then the subnet mask can be assigned by the user. The default value is 0.0.0.0.

NOTE **This item is only available in the Net Setup submenu if IP Address Assignment is Static. If IP Address Assignment is DHCP, the subnet mask is assigned by the network DHCP server and cannot be assigned by the user.**

Gateway IP Address

```
+50.00 A   -   Gateway IP Address
 +0.50 Vs      0.0.0.0
```

If IP Address Assignment is Static, then the gateway IP address can be assigned by the user. The default value is 0.0.0.0.

NOTE **This item is only available in the Net Setup submenu if IP Address Assignment is Static. If IP Address Assignment is DHCP, the gateway IP address is assigned by the network DHCP server and cannot be assigned by the user.**

EXAMPLE SETUP

As a precursor to operating a superconducting magnet with the Model 430 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.

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

MAGNET SPECIFICATIONS

AMI JOB #**024856-2-1** MAGNET #**33109**

TYPE: **Solenoid**

MODEL: **Custom**

FOR: **A&W CryoEngineering, Ltd.**

DATE: **23 May 2008**

Rated Central Field @ 4.2K[1]	**80 kG**
Rated Current	**85.6 amps**
Max. Field Tested	**82 kG**
Field to Current Ratio	**934 gauss/amp**
Homogeneity over a 1 cm DSV	**±0.5%**
Measured Inductance	**9.7 henrys**
Charging Voltage	**2.1 volts**
Axial Clear Bore	**3.0 inches**
Overall Length (flange to flange)	**4.74 inches**
Maximum Outside Diameter	**6.4 inches**
Weight	**41 lbs.**
Recommended Persistent Switch Heater Current	**41 mA**
Persistent Switch Heater Nominal Resistance[2]	**94.8 ohms**
Magnet Resistance in Parallel with Switch[2]	**16.0 ohms**

Mounting: **3 holes tapped for M6 X 1.0 on top flange, equally spaced on a 4.724 inch bolt circle diameter**

1. Magnet not warranted for operation above 80 kG.
2. All resistance measurements made at room temperature.

EXCELLENCE IN MAGNETICS AND CRYOGENICS

Example Magnet Specification Sheet

The figure at left 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 430 Programmer. For the purposes of this example, the AMI Model 4Q06125PS power supply will be assumed, since rated current for the example magnet is 85.6 A.

The Current Limit accessible in the Protection submenu should be set to the rated current to prevent accidental operation of the magnet above rated field/current. 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 Switch submenu.

If your magnet, Model 430 Programmer, and power supply were purchased as a system from AMI, the setup menus are preset by AMI to match the magnet purchased.

The table below provides a summary of the Model 430 Programmer setup parameters for this example.

Example Setup Configuration

Parameter	Setting
Select Supply	AMI 4Q06125PS
Stability Mode	Auto
Coil Constant[a] (kG/A)	0.934
Inductance (H)	9.7
Energy Absorber Present	NO
PSwitch Installed	YES
PSwitch Current (mA)	41.0
PSwitch Heated Time (sec)	20
PSwitch Cooled Time (sec)	20
PSwitch P/S Ramp Rate (A/sec)	10
PSwitch Cooling Gain (%)	0.0%
Current Limit (A)	85.600
Enable Quench Detect	YES
Extern Rampdown Enabled	YES
Voltage Limit (V)	3.500[b]
Ramp Rate (A/sec)	0.2165[c]

a. Also referred to as the Field-to-Current Ratio. Obtained by dividing the rated field by the rated current if not explicitly stated.

b. Value is the 2.1 V charge rate plus allowances for power lead drop (typically about 10-20 milliohms) at the rated current. If a Model 601 energy absorber(s) is present, add an additional 5 V to the value.

c. Value is obtained by dividing the magnet charging voltage (V) by the magnet inductance (H).

Ramping Functions

The ramping functions are used to control charging of the superconducting load. The Model 430 Programmer allows piecewise-linear charging profiles to be defined and executed (up to 10 segments, each with a unique ramp rate). 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 (H), 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:

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

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

A desired ramp rate should be selected by the user and entered into the Model 430 Programmer. A Voltage Limit should also be specified that is greater than or equal to the voltage calculated from the equations above plus energy absorber voltage (if installed) plus power lead voltage drop (usually less than 2 V).

Once the ramp rate and Voltage Limit are specified, the Model 430 Programmer provides two modes of ramping: *manual* and *automatic*. Manual ramping will ramp to the Current Limit via manual direction control by the user. Automatic ramping will ramp to the target field/ current automatically. Automatic ramping can be thought of as a "next point" operation, whereby the Model 430 determines the appropriate ramp direction based on the present magnet current and the target value.

NOTE **You may enter up to 10 digits beyond the decimal point within the ramping control menus. These extra digits are maintained in the internal memory of the Model 430 Programmer even though the full precision is not displayed after entry.**

Ramping States and Controls

The ramping state may be one of several values as described in the table below.

If the RAMP / PAUSE key is pressed while ramping, the PAUSED mode becomes active. To begin automatic ramping, press the RAMP / PAUSE key to deactivate the PAUSED mode. If manual ramping is desired, use either the INCR. FIELD or DECR. FIELD SHIFT+keys for manual control of ramping up or ramping down, respectively.

Ramp modes and descriptions.

Mode	Description
Ramping	Automatic ramping to the target field/current[a] is in progress.
Holding	The target field/current has been achieved and is being maintained.
Paused	Ramping is suspended at the field/current achieved at the time the PAUSED mode was entered.
Manual Up/Down	Ramping is being controlled by the manual control (INCR. FIELD and DECR. FIELD) SHIFT-key functions available on the front panel.
Zeroing Current	RAMP TO ZERO is active, and the Model 430 Programmer is ramping current to 0 A.
Zero Current	RAMP TO ZERO is still active, and the current is less than 0.1% of I_{max}.
Heating Switch	The persistent switch heater has been activated. Ramping is disabled during the persistent switch heating period.
Cooling Switch	The persistent switch heater has been deactivated. Ramping is disabled during the persistent switch cooling period.
External Rampdown	An external rampdown has been triggered. The system will rampdown using any defined rampdown ramp rates and *cannot be interrupted* until zero current is achieved.

a. The target field/current setting is discussed on page 58.

Voltage limit and ramp rate may be specified from quickly accessible SHIFT+key menus from the front panel keypad[43]. The settings for Voltage Limit and ramp rate(s) are applicable to both manual and automatic ramping.

MANUAL RAMPING

The INCR. FIELD and DECR. FIELD SHIFT+key functions control manual ramping. Manual ramping ramps field/current up or down at the defined ramp rate(s). See page 64 for details regarding the use of these SHIFT+key functions.

AUTOMATIC RAMPING

Automatic ramping differs from manual ramping in that the Model 430 Programmer automatically performs ramping in the appropriate direction to achieve the value of the target field/current setting. To use automatic ramping, enter the target field/current with which ramping is desired[44]. If

43. Refer to on page 60 and on page 63.

ramping is not PAUSED, ramping to the target field/current begins immediately. If ramping is PAUSED, ramping to the target field/current will begin when the RAMP / PAUSE key is pressed to take the Model 430 Programmer out of PAUSED mode. The ramp rate will be controlled by the preset ramp rate variables as described in on page 60.

RAMPING TO ZERO

Pressing the RAMP TO ZERO key activates an immediate ramp to zero field/current. See page 59 for details. Use the feature to zero the field/current instead of setting the target field/current to a value of zero.

FINE ADJUST OF FIELD / CURRENT IN HOLDING MODE

If the target field/current menu is active *and* the Model 430 Programmer is in HOLDING mode (indicated by a "–" Status Indicator), the fine adjust knob can be used to manipulate the output current. While at the target field/current menu, press SHIFT, followed by FINE ADJUST. This will allow fine adjustment of the field/current (see page 66).

```
+20.02 A  -  Target Current (A)‡
 +0.20 Vs      +20.0239
```

When the fine adjust knob is turned the Model 430 Programmer will follow the target current as it is adjusted, at the defined ramp rate for the segment in which it is operating. Adjustment of the current is prevented from exceeding the Current Limit specified in the Load setup menu (see page 85). The *resolution* of the adjustment is 15 digits, which is greater than the resolution of the display.

When the field/current is adjusted to the desired value, press the ENTER key to keep that value as the target field/current. If any other operation is performed before ENTER is pressed, the target field/current value will revert back to what it was before adjustment using the fine adjust knob was initiated, and the current will immediately begin ramping back to that value.

44. See page 58.

PERSISTENT SWITCH CONTROL

The Model 430 Programmer 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 Model 430 Programmer using the PERSIST. SWITCH CONTROL key[45], or remotely through a communications interface. The persistent mode of the magnet is indicated by the MAGNET IN PERSISTENT MODE LED[46].

See page 55 for details of the use of the PERSIST. SWITCH CONTROL key.

NOTE **The following procedures include several automatically sequenced steps once initiated. It is possible to interrupt the process at any point by pressing the SHIFT+ESC keys. Please note that the state in which the system will remain after this interruption depends on the specific active step during which the SHIFT+ESC was pressed. Use this abort override keystroke with caution.**

PROCEDURE FOR INITIAL HEATING OF THE SWITCH

The Model 430 Programmer remembers the state of the persistent switch during the time that the Programmer is de-energized. If the Model 430 is turned on when its shut down state was such that the persistent switch was heated and commanding zero current (the normal state after the magnet is discharged), the following screen will be displayed.

```
0.00 A   P  Mode: Paused
0.00 Vs     PSwitch Heater: OFF
```

In order to charge the magnet, the persistent switch heater must be energized. Perform the following steps.

45. See page 55.
46. See page 67.

1. Turn on the persistent switch heater by pressing the PERSIST. SWITCH CONTROL key to heat the persistent switch heater.

```
0.00 A   ◆  Mode: Heating Switch (4)
0.00 Vs     PSwitch Heater: ON
```

NOTE **If the PSwitch Transition setting[47] is set to Timer, the number in parentheses in the display indicates the number of seconds remaining in the timer countdown. If the PSwitch Transition setting is set to Magnet Voltage, the number in parentheses is the running magnet voltage variance. For the magnet voltage-based switch transition, a variance value of zero indicates the switch is in the cooled state.**

2. After the persistent switch heater has been heated for the preset heating time specified by the PSwitch Heated Time setting, or a transition is detected by the magnet voltage-based option, the display will show the default display and wait at zero current for a command from the operator. The magnet is no longer isolated from the power supply output.

```
0.00 A   P  Mode: Paused
0.00 Vs     PSwitch Heater: ON
```

PROCEDURE FOR ENTERING PERSISTENT MODE

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

1. Use either automatic or manual ramping to achieve the desired field or current in the magnet.
2. The Model 430 Programmer must be in either the HOLDING or PAUSED mode at the target field or current.
3. The Model 430 Programmer must be at the default field/current display.[48]
4. Press the PERSIST. SWITCH CONTROL key to turn off the persistent switch heater and automatically ramp the power supply to zero current:
    a. After the PERSIST. SWITCH CONTROL key is pressed, the Model 430 Programmer requests that the ENTER key be pressed as

47. Refer to page 82.
48. Refer to page 48.

a confirmation that the magnet should be placed in persistent mode.[49]

```
+50.00 A   -  Press ENTER to begin
  0.00 Vm     Persistent Mode
```

b. When ENTER is pressed, the persistent switch is cooled for the preset persistent switch cooling time (set by the PSwitch Cooled Time[50]). The display indicates that the persistent switch is being cooled and indicates the number of seconds (4 in this example) remaining in the cooling cycle for timer-based switch transitions, or *optionally* indicates the running variance of the magnet voltage for magnet voltage-based switch transitions.

```
+50.00 A   ◊ Mode: Cooling Switch (4)
 +0.01 Vm     PSwitch Heater: OFF
```

NOTE **For the magnet voltage-based switch transitions, a variance value of zero indicates a cooled switch. Therefore, during the cooldown the display will show a seemingly random sequence of numbers that should gradually decrease and eventually decay to a value of zero. Once the variance remains at zero for at least five seconds, the switch will be considered cooled.**

c. When the cooled time is complete, the green MAGNET IN PERSISTENT MODE LED will illuminate and the power supply will ramp to zero at the PSw P/S Ramp Rate value[51].

```
+42.89 A   ↓   Mode: Power Supply ramping
  0.00 Vm            to zero current
```

NOTE **The magnet voltage (Vm) is monitored during the power supply ramp to zero. For a cooled switch, the magnet voltage should remain at zero. The following steps d through f apply only if the magnet voltage does *not* remain at zero.**

49. Pressing the ESC key will terminate the command and return the Model 430 Programmer to the default screen.
50. Refer to on page 83 for timer-based switch transitions.
51. Refer to on page 84.

d. *If the magnet voltage exceeds 0.5 V during this ramp to zero*, the Model 430 Programmer beeps to indicate the persistent switch did not transition to the superconducting state. The Model 430 will then turn the switch heater back on *immediately* and then begin ramping the field/current back to the value before the present cooling cycle initiation:

```
+45.39 A   ↑   Mode: Power Supply Ramping
 +1.52 Vm      to match magnet field
```

NOTE **The ramp back to the value before the cooling cycle was initiated can be interrupted at any time by pressing the** RAMP/PAUSE **key. The ramping will then PAUSE and hold.**

e. When the field/current reaches the value before the cooling cycle initiation, the display will indicate the persistent mode transition malfunction:

```
+50.00 A   -   Mode: Paused w/PSW error
 +0.06 Vm      Press ENTER to continue
```

f. After pressing ENTER, the Model 430 Programmer will revert to the default field/current display.

```
+50.00 A   P   Mode: Paused
 +0.00 Vm      PSwitch Heater: ON
```

5. If there is no magnet voltage error during the rampdown, and after the power supply is finished ramping to zero, the following screen will be displayed:

```
  0.00 A   -   Magnet in Persistent Mode
  0.00 Vm      Press PER.SW.CTRL. to exit
```

NOTE **If desired, press the** ESC **key in the above display to return the Model 430 Programmer to the default display.**

```
  0.00 A   -   Mode: Zero Current
  0.00 Vm      PSwitch Heater: OFF
```

NOTE **Refer to page 58 for the procedure to display the magnet current that was established when the persistent switch was cooled.**

6. If desired, the power supply system can be de-energized. Turn the power supply off first followed in a few seconds by the Model 430 Programmer.

NOTE **The Model 430 Programmer will store the state of the magnet in memory and assist the user in exiting the persistent mode when the Model 430 Programmer is next turned on (discussed in the following paragraphs).**

PROCEDURE FOR EXITING PERSISTENT MODE

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

1. If the Model 430 Programmer *has not been* powered off since the magnet was placed in persistent mode, *proceed to step 3*.
2. If the Model 430 Programmer *has been* powered off since the magnet was placed in persistent mode, complete the following steps (a) and (b) below before proceeding to step 3.

    a. Energize the Model 430 and wait for the prompt on the Model 430 display and then energize the power supply.

```
0.00 A   P   Turn on power supply
0.00 Vs      Press ENTER to continue
```

    After the power supply has been on for a few seconds[52], press ENTER to clear the Model 430 screen prompt.

    b. When ENTER is pressed, the display will indicate that the magnet was in persistent mode[53] when the Model 430 Programmer was turned off (and display the magnet current that was established when the persistent switch was cooled).

```
Magnet in Persistent Mode (13.5A). Use
PERSIST SWITCH CONTROL to exit Per. Mode
```

52. If the power supply is an AMI 4Q06125PS Type, wait for the audible click of the relay before pressing ENTER on the Model 430.
53. The MAGNET IN PERSISTENT MODE LED will also be illuminated.

3. Press PERSIST. SWITCH CONTROL and the Model 430 display prompts with:

```
0.00 A  P  Press ENTER to exit
0.00 Vs    Persistent Mode
```

NOTE **Should the user desire not to exit persistent mode, press ESC to return to the default field/current display. If the PERSIST. SWITCH CONTROL key is later pressed, the Model 430 Programmer will execute steps 4 through 7, below.**

NOTE **If persistent mode is not exited and it is later desired to display the magnet current that was established when the persistent switch was cooled, refer to on page 58 for the procedure.**

4. When ENTER is pressed, the power supply is ramped to the current that was flowing in the magnet at the time the persistent mode was entered. The power supply will ramp at the PSw P/S Ramp Rate value[54].

```
+11.72 A  ↑  Mode: Power Supply ramping
 +0.23 Vs          to magnet current
```

5. The persistent switch heater is heated for the preset heating time as set by the PSwitch Heated Time variable[55]. Optionally, if the PSwitch Transition is set for magnet voltage, the magnet voltage variance will be displayed. The variance should transition from a value of zero to some number when the switch transitions to the heated state.

```
+50.00 A  ◊  Mode: Heating Switch (4)
 +0.56 Vs    PSwitch Heater: ON
```

54. Refer to on page 84.

55. Refer to on page 83. The (4) in the display indicates the number of seconds remaining in the heating cycle (4 in this example) for timer-based switch transitions, or optionally the magnet voltage variance for magnet voltage-based transitions.

NOTE **The magnet voltage (Vm) is monitored during the switch heating cycle. If the voltage is greater than 0.5 V, the Model 430 Programmer will beep and display a message to indicate a mismatch between the magnet current and power supply current.**

```
+50.00 A   ◊  Mode: Heating Switch (4)
 +0.86 Vm     *** Current Mismatch ***
```

NOTE **This mismatch in current indicates the magnet current (and therefore the field) has decayed significantly during the time the magnet was in persistent mode. Since this is not a critical error[56], the screen will change back to the default display typically at some field/current less than the last recorded persistent value.**

```
+47.59 A  P  Mode: Paused
  0.00 Vm    PSwitch Heater: ON
```

6. After the Model 430 Programmer has completed this persistent switch heating operation, the display reads:

```
+50.00 A  P  Mode: Magnet in Driven Mode
  0.00 Vm    Press ENTER to continue
```

7. After ENTER is pressed, the default field/current status screen is displayed with the power supply in the pause mode:

```
+50.00 A  P  Mode: Paused
  0.00 Vm    PSwitch Heater: ON
```

56. This current mismatch could be indicative of a problem with the magnet persistent joints.

TOGGLING THE STATE OF THE PERSISTENT SWITCH HEATER

The state of the persistent switch can be toggled by pressing SHIFT and then the PERSIST. SWITCH CONTROL key. By toggling the state of the heater in this manner, there will be no power supply ramping or other automatic functions.

ENTERING PERSISTENT MODE WITHOUT AUTOMATIC RAMP TO ZERO

1. Place the Model 430 Programmer in the HOLDING or PAUSED mode at the desired field or current.
2. Press the SHIFT and then the PERSIST. SWITCH CONTROL key to turn off the persistent switch heater current. Note that the Model 430 Programmer will enter the COOLING SWITCH mode and disallow any ramping during the switch cooling period.
3. If magnet current is greater than ~0.1% of the power supply maximum output current when the switch heater current is turned off, the MAGNET IN PERSISTENT MODE LED will illuminate.

EXITING PERSISTENT MODE WITHOUT AUTOMATIC RAMP TO LAST KNOWN PERSISTENT MAGNET CURRENT

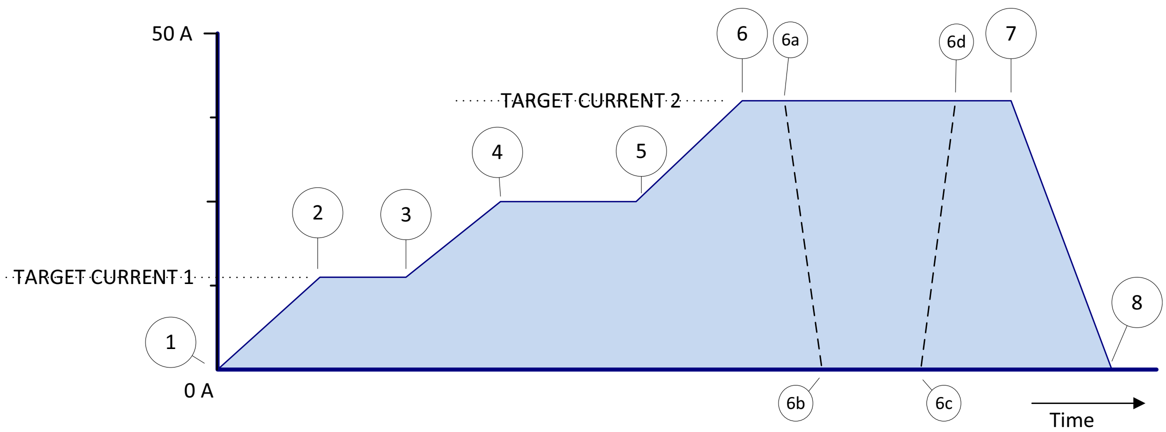
CAUTION **To avoid damage to the magnet or triggering protection circuits on the magnet, the current in the power supply should match the current that was flowing in the magnet when the persistent mode was entered.**

NOTE **For the procedure to display the magnet current that was established when the persistent switch was cooled, refer to** **page 58.**

1. Place the Model 430 Programmer in the HOLDING or PAUSED mode at the desired field or current.
2. Press the SHIFT and then the PERSIST. SWITCH CONTROL key to turn on the persistent switch heater current. Note that the Model 430 Programmer will enter the HEATING SWITCH mode and disallow any ramping during the switch heating period.
3. At the end of the switch heating period, the MAGNET IN PERSISTENT MODE LED will be turned off and the Model 430 Programmer will be in the PAUSED mode.

RAMPING FUNCTIONS EXAMPLE

As an example of ramping to two target field/current settings, refer to figure below. Each step is labeled as 1 through 8. The Model 430 Programmer, for the purposes of the example, is assumed to be in the PAUSED mode at 0 A at the beginning of the ramping example.



Ramping to two different target field/current settings.

Point 1. The current is 0 A and the Model 430 Programmer is in the PAUSED mode. The user sets the target field/current to 13.000 A. The RAMP / PAUSE key is pressed so that the PAUSED mode is no longer active and the Model 430 begins ramping current.

Point 2. The target field/current setting of 13.000 A is achieved and the Model 430 Programmer switches to HOLDING mode.

Point 3. The user changes the ramp rate setting. The user also sets a new value of +40.000 A for the target field/current. As soon as the new target field/current is entered, the Model 430 Programmer automatically begins ramping at the specified ramp rate.

Point 4. The user presses the RAMP / PAUSE key at a current of 25.15 A and the PAUSED mode is activated. The Model 430 Programmer maintains the current in the PAUSED mode.

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

Point 6. The target field/current setting of +40.000 A is achieved and the Model 430 Programmer switches to HOLDING mode. At this point the user deactivates the persistent switch heater by pressing the PERSIST. SWITCH CONTROL key, which removes the magnet from the circuit.

Point 6a. The dashed line between point 6a and 6b is the rapid ramping down of the power supply current which automatically happens after the PSwitch Cooled Time has elapsed. Note that the magnet current remains at the Point 6 value when the magnet was placed in persistent mode.

Point 6c. The user presses the PERSIST. SWITCH CONTROL key which rapidly ramps the power supply output to the current that is flowing in the magnet. The power supply matches the magnet current at point 6d.

Point 7. The user again increases the ramp rate and presses the RAMP TO ZERO key to begin ramping to zero current. The Model 430 Programmer automatically ramps the current to 0 A.

Point 8. The Model 430 Programmer switches to ZERO CURRENT mode at 0 A current when achieved and holds at this current until further commands are issued by the user.

QUENCH DETECTION

The Model 430 Programmer continuously monitors the superconducting magnet load and can automatically detect a field/current quench condition. If a quench is detected, the MAGNET QUENCH LED will be illuminated and the display will appear as shown below.

```
+44.36 A      Quench Detect @ +80.56 A
  0.00 Vs     PSwitch Heater: ON
```

QUENCH DETECTION METHOD

The *primary* method for quench detection is a continual internal comparison between the reference current and the measured current. If the measured current for the system develops a mismatch to the reference (i.e. the desired control value), then if the mismatch exceeds a predefined margin a quench detection will trigger.

Optionally, if the Model 430 is configured for external temperature input, the quench detection logic can utilize a measured temperature (such as from a cold head of a cryogenic refrigerator). If the measured temperature exceeds some predefined safe limit, the Model 430 will trigger a quench detection.

The Model 430 may also be configured to use *both* the current mismatch and temperature detection methods and trigger a quench if either indicate a problem.

NOTE **The Model 430 quench detection features should *never* be relied upon as the primary quench safing for *any* magnet system. The purpose of the Model 430 quench detection is simply to avoid dumping any *additional energy* into a magnet system that has *already* quenched. The only action the Model 430 can take is to force the power supply voltage output to zero volts and hold. Superconducting magnets should be internally designed to be safe in the event of a quench without any input from the Model 430.**

When a quench is detected, the Model 430 automatically sets the power supply output voltage to zero volts, provides a quench output signal (dry contacts) to the rear panel Quench I/O connector (see page 197 of the *Appendix* for the connector pinout), and will not respond to further input until the RESET QUENCH (SHIFT+3) key is used to clear the quench detect condition, or until the quench condition is cleared by a remote command.

If the RESET QUENCH key has been locked[57], the user will be asked to enter the password to clear the quench. The entry of this password will not unlock this reset quench feature, but will only reset the current quench event so operation may resume. Enter the password followed by the ENTER key to reset the quench and continue.

```
+44.36 A      Enter Password*
  0.00 Vs     _
```

When the RESET QUENCH key is used to clear the quench condition or a remote clear command is issued, the Model 430 Programmer will automatically enter the PAUSED mode and will attempt to maintain the current present at the point the quench condition was cleared.

EXTERNAL QUENCH DETECTION

The rear panel Quench I/O connector provides pins for external quench input (contact closure — see page 197 of the *Appendix* for the connector pinout). If the quench input is asserted, then the Model 430 Programmer interprets this input as indication of a quench condition and the Model 430 automatically sets the power supply output voltage to zero and will not respond to further input until the RESET QUENCH key is used 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 disconnected 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 430 Programmer, the RESET QUENCH (SHIFT+3) key will be unable to clear the quench condition.**

DISABLING INTERNAL QUENCH DETECTION

The internal quench detection feature may be disabled in the Load submenu[58]. However, the rear panel Quench I/O connector output remains active at all times.

57. See page 96.

58. See page 86.

If the internal quench detection feature is disabled, the Model 430 Programmer attempts to limit the error between the commanded current and the present 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 430 will follow the magnet current to zero unless the user intervenes.

If the rear panel Quench I/O connector is asserted, the Model 430 will force the power supply output to zero volts regardless of whether the internal quench detection is enabled or disabled.

In the event that the persistent switch becomes normal without user or remote activation of the switch heater control, the Model 430 Programmer will match the magnet current and attempt to stabilize the load *if the internal quench detection feature is disabled*. If the internal 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 real-time setpoint current of the Model 430.

EXTERNAL RAMPDOWN

This feature[59] is useful in any application requiring magnet rampdown in response to any external event that can be signaled by the closure of a pair of electrical contacts[60].

The user input for initiating external rampdown is provided on the rear panel of the Model 430 Programmer. The process is started by shorting, for at least 10 milliseconds, the input connections through closure of user-supplied external contacts. Once triggered, rampdown of the magnetic field of the magnet is initiated.

NOTE **Operator intervention (such as** RAMP|PAUSE**,** ESC**,** SHIFT+ESC**, etc.) is inhibited until rampdown is completed and the external rampdown signal is cleared. There is no abort function provided, however the quench detection feature of the Model 430 remains active during the rampdown.**

The external rampdown feature is ideally suited for use with AMI's Model 1700 with the liquid helium level monitor option in wet magnet systems. The Model 1700 has externally accessible normally-open relay contacts that close whenever the liquid helium level drops below a preset level.

59. When enabled. See page 91.

60. Refer to page 198. The contact closure time must be at least 10 milliseconds to ensure it doesn't fall between the sampling points of the Model 430 Programmer.

When connected to the Model 430 Programmer, these contacts can signal the Model 430 to safely and automatically ramp the magnet field to zero, thereby preventing a magnet quench due to low liquid helium level in the system.

EXTERNAL RAMPDOWN WHILE IN PERSISTENT MODE

The following steps and associated screen displays describe the process that occurs after external rampdown is initiated while the magnet is in persistent mode:

1. The Model 430 Programmer first ramps the power supply to the magnet current.

```
 +3.92 A  ↑  Mode: Ramping
 +0.17 Vs    PSwitch Heater: OFF
```

2. Once the power supply is at the magnet current, the FIELD AT TARGET LED will light and the unit will momentarily “hold”:

```
+50.00 A  -  Mode: Holding
 +0.65 Vs    PSwitch Heater: OFF
```

3. Following a short “hold”, the persistent switch will be heated to place the power supply in control of magnet current:

```
+50.00 A  ◊  Mode: Heating Switch (4)
 +0.67 Vs     PSwitch Heater: ON
```

4. After heating (turning off) the persistent switch, the MAGNET IN PERSISTENT MODE LED extinguishes, and rampdown begins. The FIELD AT TARGET LED extinguishes.

```
+48.85 A  ↓  Ext. Rampdown in progress
 -1.68 Vs    PSwitch Heater: ON
```

5. After rampdown, the following will display:

```
  0.00 A  -  Ext. Rampdown completed
  0.00 Vs    Press ENTER to continue
```

NOTE **The external rampdown signal MUST be cleared before pressing** ENTER **will yield a response. Further operator control is inhibited until the external rampdown signal is cleared.**

6. Once the external signal has been cleared, ENTER can be pressed. User control will be re-established and the operator can continue manual operation of the system. The following will be displayed after pressing ENTER:

```
0.00 A   -   Mode: Zero Current
0.00 Vs     PSwitch Heater: ON
```

EXTERNAL RAMPDOWN WHILE NOT IN PERSISTENT MODE

When external rampdown is initiated with the magnet **not** in PERSISTENT mode, the persistent switch is either heated or not installed so there is no need for persistent switch heating. The power supply is already at (and in control of) the magnet current, so the Model 430 Programmer executes an ordinary rampdown:

1. The rampdown begins immediately as described on page 123 (step 4 of "External Rampdown while in Persistent Mode"):

```
+48.85 A  ↓  Ext. Rampdown in progress
 -1.89 Vs    PSwitch Heater: ON
```

2. The sequence continues as described for the magnet in persistent mode (see page 123, steps 5 through 6).

NOTE **After rampdown, the external rampdown signal MUST be cleared before continuing. Further operator control is inhibited until the external rampdown signal is cleared.**

SUMMARY OF LIMITS AND DEFAULT SETTINGS

The table below provides a summary of the operational limits and the default setting for all Model 430 Programmer parameters. If the user attempts to enter a value outside of the limits, the Model 430 Programmer will beep once, indicate an error, and revert to the previous setting.

References to the specifications table on page 17 indicate that the absolute limit is determined by the specific configuration of the Model 430 Programmer purchased.

Summary of Model 430 Programmer Limits and Defaults

Model 430 Setting (Units)	Absolute Limits	Default Setting[a]
Min Output Voltage (V)	0.000 to -20.000	-6.000
Max Output Voltage (V)	0.001 to +20.000	6.000
Min Output Current (A)	see table on page 17	-125.000
Max Output Current (A)	see table on page 17	125.000
V-V Mode Input Range (V)	-10.000 to +10.000	-10.000 to +10.000
Stability Setting (%)	0.0 to 100.0	0.0
Coil Constant (kG/A)	0.001 to 999.99999	1.0
Inductance (H)	0.0 to 1000.0	0.0[b]
PSwitch Current (mA)	0.0 to 125.0	10.0
PSwitch Heated Time (sec)	5 to 120	20
PSwitch Cooled Time (sec)	5 to 3600	20
PSwitch Power Supply Ramp Rate (A/sec)	same as min and max ramp rates (see table on page 17)	10
PSwitch Cooling Gain	0.0 to 100.0	0.0
Current Limit (A)	≥ Min Output Current *and* ≤ Max Output Current	80.000
Display Brightness (%)	25, 50, 75, 100	100
Voltage Limit (V)	≥ 0.001 *and* ≤ Max Output Voltage	2.000
Ramp Rate (A/sec)	see table on page 17	0.100
Target Current (A)	≤ Current Limit	5.000

a. Unless preset by factory.

b. A value of 0.0 means the inductance is not known.

Remote Interface Reference

The Model 430 Programmer provides both RS-232 and Ethernet interfaces as standard features. The serial and Ethernet interfaces may be operated simultaneously. Separate output buffers are also provided for the serial and Ethernet return data. However, for optimal performance and simplicity of programming, AMI generally 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 Ethernet port (or vice-versa), which can prove to be a useful resource.

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}` (with **0** in bold) 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 (e.g. `PS`). Default settings are shown in bold.

System-Related Commands

(see page 146 for more information)

```
*IDN?
*RST
*TST?
*LED?
<Ctrl-C>

PRINT:SERIALnumber?
PRINT:PASSword?
SETTINGS?

SYSTem:LOCal
SYSTem:REMote
SYSTem:TIME?
SYSTem:TIME:SET <date(mm/dd/yyyy) time(hh:mm:ss)>

SYSTem:ERRor?
```

Status System Commands

(see page 148 for more information)

```
*STB?
*SRE <enable_value>
*SRE?

*CLS

*ESR?
*ESE <enable_value>
*ESE?

*PSC {0|1}
*PSC?

*OPC
*OPC?
```

Supply Setup Configuration Queries

(see page 150 for more information)

SUPPly:VOLTage:MINimum?
SUPPly:VOLTage:MAXimum?

SUPPly:CURRent:MINimum?
SUPPly:CURRent:MAXimum?

SUPPly:TYPE?
SUPPly:MODE?

Load Setup Configuration Commands and Queries

(see page 152 for more information)

CONFigure:STABility:MODE {0|**1**|2}
CONFigure:STABility <*percent*>
CONFigure:STABility:RESistor {**0**|1}
CONFigure:COILconst <*value (kG/A, T/A)*>
CONFigure:INDuctance <*inductance (H)*>
CONFigure:ABsorber {**0**|1}

STABility:MODE?
STABility?
STABility:RESistor?
COILconst?
INDuctance:SENSe?
INDuctance?
ABsorber?

Switch Setup Configuration Commands and Queries

(see page 154 for more information)

CONFigure:PSwitch {0|**1**}
CONFigure:PSwitch:CURRent <*current (A)*>
CONFigure:PSwitch:TRANsition {**0**|1}
CONFigure:PSwitch:HeatTIME <*time (sec)*>
CONFigure:PSwitch:CoolTIME <*time (sec)*>
CONFigure:PSwitch:PowerSupplyRampRate <*rate (A/s)*>
CONFigure:PSwitch:CoolingGAIN <*percent*>

PSwitch:INSTalled?

PSwitch:AUTODetect?
PSwitch:CURRent?
PSwitch:TRANsition?
PSwitch:HeatTIME?
PSwitch:CoolTIME?
PSwitch:PowerSupplyRampRate?
PSwitch:CoolingGAIN?

Protection Setup Configuration Commands and Queries

(see page 155 for more information)

CONFigure:CURRent:LIMit <*current (A)*>
CONFigure:QUench:DETect {0|**1**|2|3}
CONFigure:QUench:RATE {1|2|**3**|4|5}
CONFigure:OPLimit:MODE {**0**|1|2}
CONFigure:OPLimit:ICSLOPE <*value (A/K)*>

CONFigure:OPLimit:ICOFFSET <*value (A)*>
CONFigure:OPLimit:TMAX <*value (K)*>
CONFigure:OPLimit:TSCALE <*value (K/V)*>
CONFigure:OPLimit:TOFFSET <*value (K)*>
CONFigure:RAMPDown:ENABle {**0**|1}

CURRent:LIMit?
QUench:DETect?
QUench:RATE?
OPLimit:IC?
OPLimit:TEMP?
OPLimit:MODE?
OPLimit:ICSLOPE?
OPLimit:ICOFFSET?
OPLimit:TMAX?
OPLimit:TSCALE?
OPLimit:TOFFSET?
RAMPDown:ENABle?

Misc Setup Configuration Commands and Queries

(see page 158 for more information)

CONFigure:RAMP:RATE:SEGments <*value*>
CONFigure:RAMP:RATE:UNITS {**0**|1}
CONFigure:FIELD:UNITS {**0**|1}

RAMP:RATE:SEGments?

```
RAMP:RATE:UNITS?
FIELD:UNITS?
```

Lock Configuration Commands

(see page 159 for more information)

```
CONFigure:LOCK:PSwitch:CONTRol {0|1}
CONFigure:LOCK:TARGet {0|1}
CONFigure:LOCK:RAMP-PAUSE {0|1}
CONFigure:LOCK:ZEROfield {0|1}
CONFigure:LOCK:RAMPrate {0|1}
CONFigure:LOCK:SUPPly {0|1}
CONFigure:LOCK:VOLTage:LIMit {0|1}
CONFigure:LOCK:QUench:RESet {0|1}
CONFigure:LOCK:INCR-DECR {0|1}
CONFigure:LOCK:FIELD-CURRent {0|1}
CONFigure:LOCK:FIELD:UNITS {0|1}
CONFigure:LOCK:STABility {0|1}
CONFigure:LOCK:INDuctance {0|1}
CONFigure:LOCK:VOLTage:VS-VM {0|1}
CONFigure:LOCK:VOLTMeter {0|1}
CONFigure:LOCK:FINEadjust {0|1}
CONFigure:LOCK:COILconst {0|1}
CONFigure:LOCK:CURRent:LIMit {0|1}
CONFigure:LOCK:CURRent:RATING {0:1}
CONFigure:LOCK:PSwitch:SETtings {0|1}
CONFigure:LOCK:QUench:DETect {0|1}
CONFigure:LOCK:QUench:RATE {0|1}
CONFigure:LOCK:ABsorber {0|1}
CONFigure:LOCK:RAMPDown {0|1}
CONFigure:LOCK:BRIGHTness {0|1}
CONFigure:LOCK:NETsetup {0|1}
CONFigure:LOCK:OPLimit {0|1}
```

Lock Configuration Queries

(see page 159 for more information)

```
LOCK:PSwitch:CONTRol?
LOCK:TARGet?
LOCK:RAMP-PAUSE?
LOCK:ZEROfield?
LOCK:RAMPrate?
LOCK:SUPPly?
LOCK:VOLTage:LIMit?
```

LOCK:QUench:RESet?
LOCK:INCR-DECR?
LOCK:FIELD-CURRent?
LOCK:FIELD:UNITS?
LOCK:STABility?
LOCK:INDuctance?
LOCK:VOLTage:VS-VM?
LOCK:VOLTMeter?
LOCK:FINEadjust?
LOCK:COILconst?
LOCK:CURRent:LIMit?
LOCK:CURRent:RATING?
LOCK:PSwitch:SETtings?
LOCK:QUench:DETect?
LOCK:QUench:RATE?
LOCK:ABsorber?
LOCK:RAMPDown?
LOCK:BRIGHTness?
LOCK:NETsetup?
LOCK:OPLimit?

Net Setup Configuration Commands and Queries

(see page 165 for more information)

CONFigure:IPNAME *<system name>*

IPNAME?

Ramp Target/Rate Configuration Commands and Queries

(see page page 165 for more information)

CONFigure:VOLTage:LIMit *<voltage (V)>*
CONFigure:CURRent:TARGet *<current (A)>*
CONFigure:FIELD:TARGet *<field (kG, T)>*
CONFigure:RAMP:RATE:CURRent *<segment>,<rate (A/s, A/min)>, <upper bound (A)>*
CONFigure:RAMP:RATE:FIELD *<segment>,<rate (kG/s, kG/min, T/s, T/min)>,<upper bound (kG, T)>*

VOLTage:LIMit?
CURRent:TARGet?
FIELD:TARGet?
RAMP:RATE:CURRent:*<segment>*?
RAMP:RATE:FIELD:*<segment>*?

Measurement Commands and Queries

(see page 167 for more information)

```
VOLTage:MAGnet?
VOLTage:SUPPly?
CURRent:MAGnet?
CURRent:SUPPly?
FIELD:MAGnet?
```

Ramping State Commands and Queries

(see page 168 for more information)

```
RAMP
PAUSE
INCR
DECR
ZERO

STATE?
```

Switch Heater Commands and Queries

(see page 169 for more information)

```
PSwitch {0|1}
PSwitch?
PERSistent?
```

Quench State Commands and Queries

(see page 170 for more information)

```
QUench {0|1}
QUench?

Quench:COUNT?
QUenchFile?
QUenchBackup?
```

Rampdown State Commands and Queries

(see page 171 for more information)

```
CONFigure:RAMPDown:RATE:SEGments <value>
```

`CONFigure:RAMPDown:RATE:CURRent` *<segment>*, *<rate (A/s, A/min)>*, *<upper bound (A)>*
`CONFigure:RAMPDown:RATE:FIELD` *<segment>*, *<rate (kG/s, kG/min, T/s, T/min)>*, *<upper bound (Kg, T)>*

`RAMPDown:RATE:SEGments?`
`RAMPDown:RATE:CURRent:`*<segment>*`?`
`RAMPDown:RATE:FIELD:`*<segment>*`?`

`RAMPDown:COUNT?`
`RAMPDownFile?`
`RAMPDownBackup?`

Trigger Control and Queries

(see page 174 for more information)

`*ETE` *<enable_value>*
`*ETE?`
`*TRG`

Keypress Commands

(these commands act as remote keypresses on any interface/port, see the table on page 144)

```
W_KEYSTRING_SHIFT
W_KEYSTRING_TARGET
W_KEYSTRING_ZEROFIELD
W_KEYSTRING_PERSISTENT
W_KEYSTRING_RAMPPAUSE
W_KEYSTRING_1
W_KEYSTRING_2
W_KEYSTRING_3
W_KEYSTRING_4
W_KEYSTRING_5
W_KEYSTRING_6
W_KEYSTRING_7
W_KEYSTRING_8
W_KEYSTRING_9
W_KEYSTRING_0
W_KEYSTRING_PERIOD
W_KEYSTRING_PLUSMINUS
W_KEYSTRING_ESC
W_KEYSTRING_MENU
W_KEYSTRING_RIGHT
```

```
W_KEYSTRING_LEFT
W_KEYSTRING_ENTER
W_FINE_ADJ_DELTA <value>
```

PROGRAMMING OVERVIEW

The Model 430 Programmer 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 430 Programmer also implements a status system for monitoring the state of the Model 430 through the *Standard Event* and *Status Byte* registers.

SCPI LANGUAGE INTRODUCTION

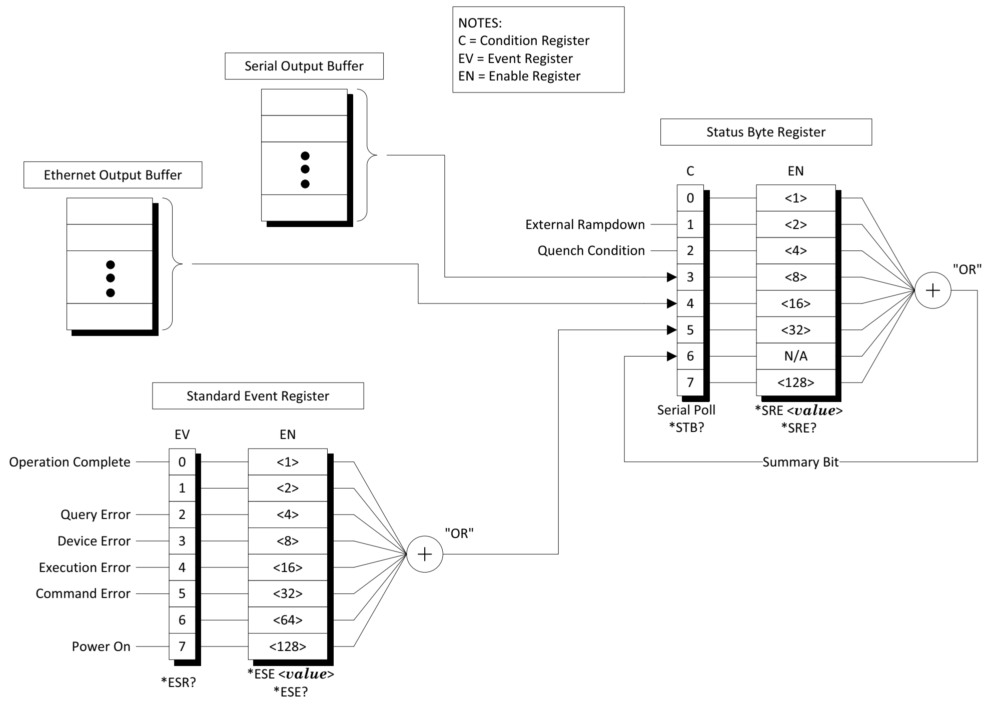
SCPI commands conform to a tree structure where commands are grouped according to common keywords. For example, commands which set a Model 430 Programmer setup or operating parameter begin with the keyword `CONFigure`. The keywords are shown in upper case and lower case to indicate acceptable abbreviations. 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 430 Programmer 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.

SCPI STATUS SYSTEM

The Model 430 Programmer status system reports various conditions of the instrument in two registers groups shown in the figure below. 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

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.



The Model 430 Programmer Status System

An *event* register latches various events. Events are not buffered, therefore once a bit is set in the event register, 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.

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 “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 the following table:

Bit Definitions for the Status Byte Register

Bit Number	Decimal Value	Definition
0 *Not Used*	1	Always “0”.
1 External Rampdown	2	An external rampdown is active.
2 Quench Condition	4	The Model 430 has detected a quench.
3 Serial Message Available	8	The serial output buffer contains unread data.
4 *Not Used*	16	Always “0”.
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”.

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. 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 power is turned off and then back on.

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 Model 430 Programmer was configured for `*PSC 1` (power-on status clear). The enable register set-

ting is persistent if the Model 430 Programmer is configured for *PSC 0 (no status clear on power-on).

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 does not clear bit 6 of the Status Byte register.

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 Model 430 Programmer 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.

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 the figure on page 136). 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 the table on the following page. To query the Model 430 Programmer for the details of a reported error in the Standard Event register, use the SYSTem:ERRor? query. See page 176 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 power is turned off and then back on.

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 Model 430 Programmer was configured for *PSC 1 (power-on status clear). The enable register set-

ting is persistent if the Model 430 Programmer is configured for `*PSC 0` (no status clear on power-on).

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.

COMMAND HANDSHAKING

The Model 430 Programmer 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 430 can execute. If the Model 430 Programmer 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.

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. This command is useful should many commands be sent to the Model 430 Programmer in rapid succession.

NOTE **The *OPC command historically is designed to generate an SRQ which can be monitored by a serial poll over a GPIB interface, which operates outside of the normal command queue. Since a GPIB interface is not available in the Model 430, the *OPC command has limited value (as it would require polling the status registers *using* the command queue) and should be ignored in favor of the *OPC? query documented below for the serial and Ethernet interfaces.**

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 a simple solution for determining completed remote command execution (because *commands* do not send a reply). It is also unambiguous during simultaneous serial and Ethernet operation since the result is returned directly to the requesting communication interface.

An example of a sequence of commands using the `*OPC?` query to handshake is the following:

```
CONF:CURR:TARG 50.0;
CONF:RAMP:RATE:CURR 1,0.1,80.0;
CONF:VOLT:LIM 5.0;
*OPC?;
```

The above example sets the target current to 50.0 A, the ramp rate segment #1 to 0.1 A/s up to 80.0 A, the voltage limit to 5.0 V, and sends as the fourth command the `*OPC?` query for determining when execution all of the commands (including `*OPC?`) is completed. The `*OPC?` query will return a "1" to the requesting interface when it executes.

RS-232 Configuration

The Model 430 Programmer uses the following *fixed* parameters related to the RS-232 interface:

- *Baud Rate*: 115200
- *Parity:* No Parity
- *Data Bits*: 8 Data Bits
- *Number of Start Bits*: 1 bit
- *Number of Stop Bits*: 1 bit
- *Flow Control*: Hardware (RTS/CTS)

Serial Connector

An IBM-compatible computer's serial port can be directly connected to the Model 430 Programmer via a standard DB9-female-to-DB9-female null modem serial cable. Refer to your computer's documentation to determine which serial ports are available on your computer and the required connector type.

The Model 430 Programmer is classified as a DTE (Data Terminal Equipment) device. It uses the standard DB9 male connector and identical pinout used on IBM-compatible computers. The RS-232 connector pinout for the Model 430 Programmer is fully documented on page 202 in the *Appendix*.

Termination Characters

All commands and queries are transmitted and received as ASCII values and are case insensitive. The Model 430 Programmer always transmits *<CR><LF>* (a *carriage return* followed by a *linefeed*) at the end of an RS-232 transmission. The Model 430 Programmer can accept *<CR>*, *<LF>*, *<CR><LF>*, or *<LF><CR>*, or a semicolon (**;**) as termination characters from an external computer.

Ethernet Configuration

The Model 430 Programmer provides a 10/100Base-T Ethernet interface as a standard feature. It complies with the IEEE 802.3u 100Base-TX and 802.3 10Base-T standards.

The Model 430 Programmer allows its IP address, subnet mask and gateway IP address to be assigned either statically or dynamically. To make these values static and assign them manually, set IP Address Assignment to Static (see page 103) and then set the values using the parameters under the Net Setup submenu (beginning on page 104). To make the values dynamically assigned by a network DHCP server, set IP Address Assignment to DHCP.

The system name (also known as *host name* or *computer name*), can be set using remote communications (either Ethernet or RS-232); it cannot be edited using the front panel keypad.

All network parameters (even those assigned by a DHCP server) can be viewed using the Net Settings submenu (see page 101).

ETHERNET CONNECTOR

The Model 430 Programmer uses a standard RJ-45 jack for Ethernet communications. The Ethernet jack pinout is fully documented on page 201 in the *Appendix*.

TERMINATION CHARACTERS

All commands and queries are transmitted and received as ASCII values and are case insensitive. The Model 430 Programmer always transmits *<CR><LF>* (a *carriage return* followed by a *linefeed*) at the end of an Ethernet transmission. The Model 430 can accept *<CR>*, *<LF>*, *<CR><LF>*, or *<LF><CR>*, or a semicolon (**;**) as termination characters from an external computer.

PORT ASSIGNMENTS

The Model 430 accepts connections to ports 23 and 7180. Port 7180 is recommended for general command/query operation. When a connection is successfully established to the Model 430, the following "hello" message is immediately returned:

```
American Magnetics Model 430 IP Interface\r\nHello.\r\n
```

Multiple connections to port 7180 are allowed. Multiple connections to port 23 are also allowed, but the special broadcast protocol described in the following section will only occur for the *last connection* made to port 23.

TELNET PORT 23 BROADCAST PROTOCOL

Port 23 has a special function in that the display characters are broadcast each time the display is internally updated by the Model 430. This occurs approximately every 250 milliseconds. This feature is intended to allow the user to optionally show a remote display that remains synced with the front panel display.

The broadcast message format will be as the following example output (terminated with a <CR><LF> pair):

```
MSG_DISP_UPDATE:: +50.00 A  -  Mode: Holding           ::   0.00 Vm    PSwitch Heater: ON        ::0::1::0::1::0::0
```

The `MSG_DISP_UPDATE::` is the delimiter text indicating the display text follows. The first line of the display is the text up to the next `::` delimiter pair, followed by the second line of the display up to the next `::` pair.

The state (0=OFF, 1=ON) of each front panel LED then follows delimited by `::` pairs. The LED field order is: SHIFT, FIELD AT TARGET, MAGNET IN PERSISTENT MODE, CURRENT LEADS ENERGIZED, and MAGNET QUENCH.

Therefore, the example broadcasted output above would decode to a display as follows:

```
+50.00 A   -   Mode: Holding
  0.00 Vm      PSwitch Heater: ON
```

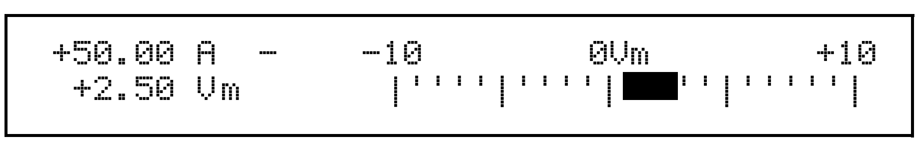
with the FIELD AT TARGET and CURRENT LEADS ENERGIZED LEDs in the ON state.

If the display is in the voltmeter mode (see page 66) for either Vs or Vm, the broadcasted message format changes to the following example output (terminated with a <CR><LF> pair):

```
MSG_VOLTMETER_UPDATE:: +50.00 A  - ::  +2.50 Vm   ::0::0::0::0::0::0::Vm::2.500000
```

The `MSG_VOLTMETER_UPDATE::` is the delimiter text indicating the voltmeter display information follows. The field/current, status indication, and voltage displays are shown first, followed by the delimited LED states in the exact same order as described above. Then the displayed voltage value name is provided followed by the final `::` pair and the actual voltage value in volts.

Therefore, the example broadcasted voltmeter output above would decode to a display as follows:



with no LEDs in the ON state.

CUSTOM DISPLAY CHARACTERS

Please note that the ramping character and certain other display characters have custom-defined codes beyond `0x7F` that do *not* map directly to ASCII equivalents. The custom character and the actual byte value that is sent in a broadcast message are shown in the table below:

Broadcasted Custom Display Characters

Character	Byte Value	Character	Byte Value
	0x80		0x86
	0x81		0x87
	0x82		0x88
	0x83		0x89
	0x84		0x8A
	0x85		

BROADCASTED KEYPRESSES AND EVENTS

In addition to the broadcasted display message, there are additional broadcast messages related to physical keypresses (via the front panel) and certain events that will be interleaved as they occur with the broadcasted display messages. Each is terminated on transmission with the <CR><LF> pair. The messages are described in the table below:

Broadcasted Keypress and Event Messages

Message (ASCII format)	Meaning
`MSG_KEY_SHIFT`	SHIFT key pressed
`MSG_KEY_TARGET`	TARGET FIELD SETPOINT key pressed
`MSG_KEY_ZEROFIELD`	RAMP TO ZERO key pressed
`MSG_KEY_PERSISTENT`	PERSIST. SWITCH CONTROL key pressed
`MSG_KEY_RAMPPAUSE`	RAMP/PAUSE key pressed
`MSG_KEY_1`	1 key pressed
`MSG_KEY_2`	2 key pressed
`MSG_KEY_3`	3 key pressed
`MSG_KEY_4`	4 key pressed
`MSG_KEY_5`	5 key pressed
`MSG_KEY_6`	6 key pressed
`MSG_KEY_7`	7 key pressed
`MSG_KEY_8`	8 key pressed

Broadcasted Keypress and Event Messages (Continued)

Message (ASCII format)	Meaning
MSG_KEY_9	9 key pressed
MSG_KEY_0	0 key pressed
MSG_KEY_PERIOD	. key pressed
MSG_KEY_PLUSMINUS	+/- key pressed
MSG_KEY_ESC	ESC key pressed
MSG_KEY_MENU	MENU key pressed
MSG_KEY_RIGHT	Right arrow key pressed
MSG_KEY_LEFT	Left arrow key pressed
MSG_KEY_ENTER	ENTER key pressed
MSG_BEEP	Audible beep emitted
MSG_EXT_RAMPDOWN_START	External rampdown activated
MSG_EXT_RAMPDOWN_END	External rampdown ended
MSG_FINE_ADJ_DELTA *<value>*	Encoder adjust delta (value sent is a positive or negative integer of the number of encoder clicks, user must convert to a meaningful delta for a given parameter being edited).

COMMAND REFERENCE

The following paragraphs present all Model 430 Programmer 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.

SYSTEM-RELATED COMMANDS

- `*IDN?`

Returns the identification string of the Model 430 Programmer. The identification string contains the manufacturer name, model number, serial number, and firmware revision code. Example output:

```
AMERICAN MAGNETICS INC.,MODEL 430,1215001,3.00
```

- `*RST`

Resets the Model 430 Programmer. This is equivalent to cycling the power to the Model 430 Programmer 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”.

- `*LED?`

Returns a comma-delimited list of the LED states with 0=OFF and 1=ON. The LED field order is: SHIFT, FIELD AT TARGET, MAGNET IN PERSISTENT MODE, CURRENT LEADS ENERGIZED, and MAGNET QUENCH. For example, the transaction:

Sent: `*LED?`
Returned: `0,1,0,1,0`

indicates the FIELD AT TARGET and CURRENT LEADS ENERGIZED LEDs are engergized.

- *<Ctrl-C>*

This clears the output buffers of the Model 430 Programmer and prepares the instrument for a new command. Status registers are unaffected. *<Ctrl-C>* corresponds to ASCII code 03.

- `PRINT:SERIALnumber?`

Returns the serial number.

- `PRINT:PASSword?`

Returns the presently set numerical password.

- `SETTINGS?`

Returns a multi-line ASCII text dump of *all* the Model 430 settings. The output of this query is terminated with two contiguous pairs of <CR><LF> characters (i.e. double terminators).

- `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, send the *RST command, press** SHIFT **followed by** MENU**, or cycle Model 430 Programmer power to re-enable the front panel controls.**

Disables all front panel controls. If the Model 430 Programmer 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 ↑  Mode: Ramping
 +1.50 Vs *  PSwitch Heater: ON
```

Asterisk Indicating the Model 430 is in Remote Mode

- `SYSTem:TIME?`

Returns the date and time of the Model 430 Programmer in the format *mm/dd/yyyy hh:mm:ss*. Time is always reported in 24-hour format. Example output: `05/02/2017 21:13:50`

- `SYSTem:TIME:SET` *<date(mm/dd/yyyy) time(hh:mm:ss)>*

Sets the date and time of the Model 430 Programmer using the format *mm/dd/yyyy hh:mm:ss*. Time is always set in 24-hour format.

- `SYSTem:ERRor?`

Queries the error buffer of the Model 430 Programmer. Up to 10 errors are stored in the 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 176 for a complete description of the error buffer and messages.

STATUS SYSTEM COMMANDS

The status system register groups and commands are illustrated the figure on page 136.

- `*STB?`

Returns the contents of the Status Byte register. The `*STB?` command does not clear 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 page 137 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 a decimal sum which corresponds to the binary-weighted sum of the contents of the Standard Event register.

- `*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 page 139 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 139 for a complete discussion.

- `*OPC?`

Returns “1” to the requesting interface when executed. See page 140 for more information.

SUPPLY SETUP CONFIGURATION QUERIES

The Supply Setup Configuration Queries provide read-only access to the setup functions available for the Supply Setup submenu (page 70).

- `SUPPly:TYPE?`

Returns the index according to the table below for the selected power supply type according to the table below. This value can be configured only via front panel operation of the SUPPLY setup menu.

Return Values and Meanings for `SUPPly:TYPE?` Query

Return Value	Meaning
0	AMI 12100PS
1	AMI 12200PS
2	AMI 4Q05100PS
3	AMI 4Q06125PS
4	AMI 4Q06250PS
5	AMI 4Q12125PS
6	AMI 10100PS
7	AMI 10200PS
8	HP 6260B
9	Kepco BOP 20-5M
10	Kepco BOP 20-10M
11	Xantrex XFR 7.5-140
12	Custom
13	AMI 08150PS
14	AMI 05120PS
15	AMI 05240PS
16	AMI 05360PS
17	AMI 05600PS
18	AMI 03300PS

• `SUPPly:VOLTage:MINimum?`

Returns the minimum *power supply* compliance setting in volts. This value can be configured only via front panel operation using the Supply submenu and is set automatically when a preset supply type is selected.

• `SUPPly:VOLTage:MAXimum?`

Returns the maximum *power supply* compliance in volts. This value can be configured only via front panel operation using the Supply submenu and is set automatically when a preset supply type is selected.

• `SUPPly:CURRent:MINimum?`

Returns the minimum output current capacity of the *power supply* in amperes. This value can be configured only via front panel operation using the Supply submenu and is set automatically when a preset supply type is selected.

• `SUPPly:CURRent:MAXimum?`

Returns the maximum output current capacity of the *power supply* in amperes. This value can be configured only via front panel operation using the Supply submenu and is set automatically when a preset supply type is selected.

• `SUPPly:MODE?`

Returns an integer value corresponding to the voltage output mode according to the table below:

Return Values and Meanings for `SUPPly:MODE?` Query

Return Value	Meaning
0	+0.000 to +5.000
1	+0.000 to +10.000
2	-5.000 to +5.000
3	-10.000 to +10.000
4	-5.000 to +0.000
5	+0.000 to +8.000

This value can be configured only via front panel operation using the Supply submenu and is set automatically when a preset supply type is selected.

LOAD SETUP CONFIGURATION COMMANDS AND QUERIES

The Load Setup Configuration Commands and Queries provide read/ write access to the setup functions available for the Load Setup submenu (page 75).

- `CONFigure:STABility:MODE {0|`**`1`**`|2}`

"0" configures the stability mode as "Auto", "1" is "Manual", and "2" is "Test". If "Auto" mode is selected and an inductance value is not specified (i.e. the inductance entry is zero), the Model 430 will beep once, generate an error, and revert to "Manual" stability mode. Manual mode is the default value.

In "Auto" stability mode, the stability setting is automatically adjust per the presence or absence of a persistent switch, the presence or absence of a stabilizing resistor, and the estimated or measured magnet inductance.

- `STABility:MODE?`

Returns "0" for "Auto" stability mode, "1" for "Manual", and "2" for "Test".

- `CONFigure:STABility` <*percent*>

Sets the stability setting in percent. Valid range is 0.0 to 100.0%.

- `STABility?`

Returns the stability setting in percent.

- `CONFigure:STABility:RESistor {`**`0`**`|1}`

An argument of "0" specifies no stabilizing resistor is installed. "1" indicates a stabilizing resistor is installed. "0" is the default value.

- `STABility:RESistor?`

Returns "0" for no stabilizing resistor and "1" for an installed stabilizing resistor.

- `CONFigure:COILconst` <*value (kG/A, T/A)*>

Sets the coil constant (also referred to as the field-to-current ratio) per the selected field units. The coil constant must be set to a non-zero, positive value in order to command or query the Model 430 Programmer in units of field.

• `COILconst?`

Returns the coil constant setting in kG/A or T/A per the selected field units.

• `CONFigure:INDuctance` <*inductance (H)*>

Sets the currently-connected magnet inductance in Henries.

• `INDuctance:SENSe?`

Initiates a direct measurement of the currently connected magnet. The measurement requires the magnet to be ramping up or down while not passing through a ramp segment change during the measurement. If these conditions are not met, the Model 430 will beep once, generate an error, and exit the measurement. Otherwise, this will return a measurement of the magnet inductance in Henries. The measured value will automatically be stored as the currently-connected inductance.

NOTE **The inductance measurement *requires* the magnet voltage input to the rear panel Magnet Station connector as described on** **page 191.** **Please note that some magnet system manufacturers do not provide magnet voltage taps.**

NOTE **This remote command blocks communication for several seconds on all ports until the measurement process completes or is interrupted.**

• `INDuctance?`

Returns the currently-connected magnet inductance in Henries.

• `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.

SWITCH SETUP CONFIGURATION COMMANDS AND QUERIES

The Switch Setup Configuration Commands and Queries provide read/write access to the setup functions available for the Switch Setup submenu (page 80).

- `CONFigure:PSwitch {0|1}`
- `PSwitch:INSTalled?`

“0” indicates that a persistent switch is not installed on the connected superconducting magnet. “1” indicates that a persistent switch is installed. The default value is “1”. If a persistent switch is installed, the persistent switch heated current should be specified. Heating/cooling times should also be specified for timer-based switch transitions.

- `CONFigure:PSwitch:CURRent` <*current (mA)*>

Sets the persistent switch heater current in mA.

- `PSwitch:CURRent?`

Returns the persistent switch heater current setting in mA.

- `PSwitch:AUTODetect?`

Executes the auto-detection algorithm (refer to page 81) and returns the appropriate persistent switch heater current in mA. Note that after this value is returned, it can be entered into the Model 430 Programmer using the `CONFigure:PSwitch:CURRent` command.

NOTE **This remote command blocks communication on all ports until the auto-detection process completes or is interrupted.**

- `CONFigure:PSwitch:TRANsition {0|1}`

Sending a value of “0” selects the timer-based switch transition detection. Sending “1” selects the magnet voltage-based transition detection. Timer-based transition detection is the default.

- `PSwitch:TRANsition?`

“0” return value indicates timer-based switch transitions. “1” indicates magnet voltage-based transitions.

- `CONFigure:PSwitch:HeatTIME` <*time (sec)*>

Sets the time required in seconds for the persistent switch to become resistive after the persistent switch heater has been activated.

• `PSwitch:HeatTIME?`

Returns the persistent switch heated time in seconds.

• `CONFigure:PSwitch:CoolTIME` <*time (sec)*>

Sets the time required in seconds for the persistent switch to become superconducting after the persistent switch heater has been deactivated.

• `PSwitch:CoolTIME?`

Returns the persistent switch cooled time in seconds.

• `CONFigure:PSwitch:PowerSupplyRampRate` <*rate (A/s)*>

Sets the ramp rate that will be used by the power supply to ramp the current[1] during the PERSIST. SWITCH CONTROL operation when the switch is in a cooled state. This ramp rate can be much higher than when the switch is heated and the magnet is in the circuit. For more information as to how this function operates, refer to page 55.

• `PSwitch:PowerSupplyRampRate?`

Returns the power supply ramp rate used to change the power supply output when the magnet persistent switch is cool. The units are A/sec.

• `CONFigure:PSwitch:CoolingGAIN` <*percent*>

Sets the persistent switch cooling gain in percent.

• `PSwitch:CoolingGAIN?`

Returns the persistent switch cooling gain in percent.

PROTECTION SETUP CONFIGURATION COMMANDS AND QUERIES

The Protection Setup Configuration Commands and Queries provide read/write access to the setup functions available for the Protection Setup submenu (page 85).

• `CONFigure:CURRent:LIMit` <*current (A)*>

Sets the 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. This value is typically provided by the magnet

1. While the magnet is in persistent mode.

manufacturer as the maximum safe limit of magnet operation (for AMI magnets it is the Magnet Rated Current, see page 105).

• `CURRent:LIMit?`

Returns the Current Limit in amperes.

• `CONFigure:QUench:DETect {0|`**1**`|2|3}`

Sending “0” disables the automatic quench detection function of the Model 430 Programmer. “1” enables the current-mismatch quench detection function of the Model 430. “2” enables the temperature-limit quench detection function. “3” enables both the current-mismatch and temperature-limit methods of quench detection with either able to trigger a quench. See page 120 for more information. “1” is the default value.

• `QUench:DETect?`

Returns “0” indicating automatic quench detection is disabled, or “1” indicating that the current-mismatch automatic quench detection is enabled. “2” indicates temperature-limit quench detection is enabled. “3” indicates *both* current-mismatch and temperature-limit quench detection methods are enabled.

• `CONFigure:QUench:RATE {1|2|`**3**`|4|5}`

Sets the value of the quench detect sensitivity. The range is from 1 to 5 in integer increments. “1” indicates the most sensitivity. “5” is the least sensitivity. “3” (normal) is the default value.

• `QUench:RATE?`

Returns the value of the quench detect sensitivity from 1 to 5 in integer increments where “1” is the most sensitivity and “5” is the least.

• `OPLimit:IC?`

Returns the present value of the temperature-based maximum (i.e. critical) current limit, ***Ic***, specified by the equation documented on page 88.

• `OPLimit:TEMP?`

Returns the temperature in units of Kelvin read from the Auxiliary Input 3 (see page 200).

• `CONFigure:OPLimit:MODE {`**0**`|1|2}`

Sets the Protection Mode for the Operational Limits submenu (refer to section on page 88). Sending “0” sets the mode is Off. Sending “1” sets the mode to “On Entry”. Sending “2” sets the mode to “Cont f(T)”. “0” is the default value.

• `OPLimit:MODE?`

Returns “0” indicating the Protection Mode for the Operational Limits submenu is Off. Returns “1” indicating the mode is “On Entry”. Returns “2” indicating the mode is “Cont f(T)”.

• `CONFigure:OPLimit:ICSLOPE` <*value (A/K)*>

Sets the *Ic Slope* value in the Operational Limits submenu. The units are amperes/Kelvin.

• `OPLimit:ICSLOPE?`

Returns the present *Ic Slope* value from the Operational Limits submenu in units of amperes/Kelvin.

• `CONFigure:OPLimit:ICOFFSET` <*value (A)*>

Sets the *Ic Offset* value in the Operational Limits submenu. The units are amperes.

• `OPLimit:ICOFFSET?`

Returns the present *Ic Offset* value from the Operational Limits submenu in units of amperes.

• `CONFigure:OPLimit:TMAX` <*value (K)*>

Sets the T_{max} value in the Operational Limits submenu. The units are Kelvin.

• `OPLimit:TMAX?`

Returns the present T_{max} value from the Operational Limits submenu in units of Kelvin.

• `CONFigure:OPLimit:TSCALE` <*value (K/V)*>

Sets the scale value in Kelvin/volts for the voltage-to-temperature conversion for the voltage value read from Auxiliary Input 3 (see page 200).

• `OPLimit:TSCALE?`

Returns the scale value in Kelvin/volts for the Auxiliary Input 3 voltage-to-temperature conversion.

- `CONFigure:OPLimit:TOFFSET` <*value (K)*>

Sets the offset value in Kelvin for the voltage-to-temperature conversion for the voltage value read from Auxiliary Input 3 (see page 200).

- `OPLimit:TOFFSET?`

Returns the offset value in Kelvin for the Auxiliary Input 3 voltage-to-temperature conversion.

- `CONFigure:RAMPDown:ENABle` {**0**|1}

Enables the external rampdown function. “1” enables while “0” disables. “0” is the default value.

- `RAMPDown:ENABle?`

Queries whether the external rampdown function is enabled. Returns “1” for enabled while “0” for disabled. “0” is the default value.

MISC SETUP CONFIGURATION COMMANDS AND QUERIES

The Misc Setup Configuration Commands and Queries provide read/write access to the setup functions available for the Misc Setup submenu (page 92).

- `CONFigure:RAMP:RATE:SEGments` <*value*>

Sets the number of ramp segments from 1 to 10. 1 is the default. See page 92 for details of the use of ramp segments.

- `RAMP:RATE:SEGments?`

Returns the number of ramp segments from 1 to 10.

- `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 430 Programmer 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 430 Programmer display and the applicable remote commands.

• `FIELD:UNITS?`

Returns “0” for field values displayed/specified in terms of kilogauss, or “1” for tesla.

LOCK COMMANDS AND QUERIES

The Lock Commands and Queries provide read/write access to all lock settings which can be accessed under the Settings Protection portion of the Misc Setup submenu. See page 93 for more information regarding the settings protection features of the Model 430 Programmer.

• `CONFigure:LOCK:PSwitch:CONTRol {0|1}`

Specifies whether use of the PERSIST. SWITCH CONTROL key is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:PSwitch:CONTRol?`

Returns “0” for use of the PERSIST. SWITCH CONTROL key unlocked, or “1” for locked.

• `CONFigure:LOCK:TARGet {0|1}`

Specifies whether use of the TARGET FIELD SETPOINT key is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:TARGet?`

Returns “0” for use of the TARGET FIELD SETPOINT key unlocked, or “1” for locked.

• `CONFigure:LOCK:RAMP-PAUSE {0|1}`

Specifies whether use of the RAMP / PAUSE key is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:RAMP-PAUSE?`

Returns “0” for use of the RAMP / PAUSE key unlocked, or “1” for locked.

• `CONFigure:LOCK:ZEROfield {0|1}`

Specifies whether use of the RAMP TO ZERO key is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:ZEROfield?`

Returns “0” for use of the RAMP TO ZERO key unlocked, or “1” for locked.

• `CONFigure:LOCK:RAMPrate {0|1}`

Specifies whether ramp rate settings are locked or unlocked. Ramp rate settings protected by this setting are: use of the RAMP RATE (SHIFT+1) menu, editing of the Ramp Segments value (under the Misc submenu) and editing of the Ramp Time Units value (under the Misc submenu). Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:RAMPrate?`

Returns “0” for ramp rate settings unlocked, or “1” for locked.

• `CONFigure:LOCK:SUPPly {0|1}`

Specifies whether the Select Supply picklist value is locked or unlocked. If the Select Supply value is Custom..., then setting Power Supply Lock to Locked also prevents the custom power supply parameters (Min Output Voltage, Max Output Voltage, Min Output Current, Max Output Current and V-V Mode Input Range) from being edited. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:SUPPly?`

Returns “0” for Select Supply picklist value unlocked, or “1” for locked.

• `CONFigure:LOCK:VOLTage:LIMit {0|1}`

Specifies whether use of the VOLTAGE LIMIT (SHIFT+2) menu is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:VOLTage:LIMit?`

Returns “0” for use of the VOLTAGE LIMIT (SHIFT+2) menu unlocked, or “1” for locked.

• `CONFigure:LOCK:QUench:RESet {0|1}`

Specifies whether use of the RESET QUENCH (SHIFT+3) command is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:QUench:RESet?`

Returns “0” for use of the RESET QUENCH (SHIFT+3) command unlocked, or “1” for locked.

• `CONFigure:LOCK:INCR-DECR {0|1}`

Specifies whether use of the INCR. FIELD (SHIFT+4) and DECR. FIELD (SHIFT+6) commands are locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:INCR-DECR?`

Returns “0” for use of the INCR. FIELD (SHIFT+4) and DECR. FIELD (SHIFT+6) commands unlocked, or “1” for locked.

• `CONFigure:LOCK:FIELD-CURRent {0|1}`

Specifies whether use of the FIELD <> CURRENT (SHIFT+5) command is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:FIELD-CURRent?`

Returns “0” for use of the FIELD <> CURRENT (SHIFT+5) command unlocked, or “1” for locked.

• `CONFigure:LOCK:FIELD:UNITS {0|1}`

Specifies whether the Field Units value is locked or unlocked (whether accessed through the FIELD UNITS (SHIFT+7) menu or under the Misc Setup submenu). Sending “0” unlocks. A “1” locks. “0” is the default value.

• `LOCK:FIELD:UNITS?`

Returns “0” for Field Units value unlocked, or “1” for locked.

• `CONFigure:LOCK:STABility {0|1}`

Specifies whether the Stability Mode and Stability Setting values are locked or unlocked (whether accessed through the STAB. (SHIFT+8) menu or under the Load submenu). Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:STABility?`

Returns “0” for Stability Mode and Stability Setting values unlocked, or “1” for locked.

- `CONFigure:LOCK:INDuctance {0|1}`

Specifies whether the Inductance and Sense Inductance? functions are located or unlocked under the Load Setup submenu. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:INDuctance?`

Returns “0” for Inductance and Sense Inductance? functions unlocked, or “1” for locked.

- `CONFigure:LOCK:VOLTage:VS-VM {0|1}`

Specifies whether use of the Vs <> Vm (SHIFT+0) command is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:VOLTage:VS-VM?`

Returns “0” for use of the Vs <> Vm (SHIFT+0) command unlocked, or “1” for locked.

- `CONFigure:LOCK:VOLTMeter {0|1}`

Specifies whether use of the VOLT METER (SHIFT+.) command is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:VOLTage:VOLTMeter?`

Returns “0” for use of the VOLT METER (SHIFT+.) command unlocked, or “1” for locked.

- `CONFigure:LOCK:FINEadjust {0|1}`

Specifies whether use of the FINE ADJUST (SHIFT +/-) command is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:VOLTage:FINEadjust?`

Returns “0” for use of the FINE ADJUST (SHIFT +/-) command unlocked, or “1” for locked.

- `CONFigure:LOCK:COILconst {0|1}`

Specifies whether the Coil Constant value (under the Load submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:VOLTage:COILconst?`

Returns “0” for Coil Constant value (under the Load submenu) unlocked, or “1” for locked.

- `CONFigure:LOCK:CURRent:LIMit {0|1}`

Specifies whether the Current Limit value (under the Load submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:CURRent:LIMit?`

Returns “0” for Current Limit value (under the Load submenu) unlocked, or “1” for locked.

- `CONFigure:LOCK:PSwitch:SETtings {0|1}`

Specifies whether persistent switch settings are locked or unlocked. Persistent switch settings protected by this setting (all under the Switch Setup submenu) are: PSwitch Installed, PSwitch Current, PSwitch Transition, PSwitch Heated Time, PSwitch Current Detect, PSwitch Cooled, PSw P/S Ramp Rate, and PSwitch Cooling Gain. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:PSwitch:SETtings?`

Returns “0” for persistent switch settings unlocked, or “1” for locked.

- `CONFigure:LOCK:QUench:DETect {0|1}`

Specifies whether the Enable Quench Detect picklist value (under the Protection Setup submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:QUench:DETect?`

Returns “0” for Enable Quench Detect picklist value (under the Protection Setup submenu) unlocked, or “1” for locked.

- `CONFigure:LOCK:QUench:RATE {0|1}`

Specifies whether use of the quench sensitivity (rate) command is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:QUench:RATE?`

Returns “0” for use of the quench sensitivity (rate) command unlocked, or “1” for locked.

- `CONFigure:LOCK:ABsorber {0|1}`

Specifies whether the Energy Absorber Present picklist value (under the Load submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:ABsorber?`

Returns “0” for Energy Absorber Present picklist value (under the Load submenu) unlocked, or “1” for locked.

- `CONFigure:LOCK:BRIGHTness {0|1}`

Specifies whether the Display Brightness picklist value (under the Misc submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:BRIGHTness?`

Returns “0” for Display Brightness picklist value (under the Misc submenu) unlocked, or “1” for locked.

- `CONFigure:LOCK:NETsetup {0|1}`

Specifies whether the Net Setup submenu is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:NETsetup?`

Returns “0” for Net Setup submenu unlocked, or “1” for locked.

- `CONFigure:LOCK:OPLimit {0|1}`

Specifies whether the Operational Limits submenu (under the Protection Setup submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:OPLimit?`

Returns “0” for Operational Limits submenu (see section on page 88) unlocked, or “1” for locked.

- `CONFigure:LOCK:RAMPDown {0|1}`

Specifies whether the External Rampdown Enabled picklist value (under the Protection Setup submenu) is locked or unlocked. Sending “0” unlocks. A “1” locks. “0” is the default value.

- `LOCK:RAMPDown?`

Returns “0” for External Rampdown Enabled picklist value (under the Protection Setup submenu) unlocked, or “1” for locked.

NET SETUP CONFIGURATION COMMANDS AND QUERIES

The Net Setup Configuration Commands and Queries provide read/write access to the `IPNAME` setting available in the Net Setup submenu (page 103).

- `CONFigure:IPNAME` <*system name*>

Sets the system name (also known as *host name* or *computer name*), the *name* by which the Model 430 Programmer is identified on a network.

NOTE **If the system name value is changed, the Model 430 Programmer power must be cycled off for at least 5 seconds and then back on to complete the change. The new value will be used internally immediately (even before cycling power off and back on), but the IPNAME? query will return the previous system name until the Model 430 Programmer is restarted.**

- `IPNAME?`

Returns the system name (also known as *host name* or *computer name*).

RAMP TARGET/RATE CONFIGURATION COMMANDS AND QUERIES

The ramp configuration commands set the various parameters required for defining and limiting piecewise-linear ramp segments.

- `CONFigure:VOLTage:LIMit` <*voltage (V)*>

Sets the ramping Voltage Limit in volts. The limit may not exceed the maximum output voltage of the power supply.

• `VOLTage:LIMit?`

Returns the ramping Voltage Limit in volts.

• `CONFigure:CURRent:TARGet` <*current (A)*>

Sets the target setpoint current in amperes.

• `CURRent:TARGet?`

Returns the target current setting in amperes.

• `CONFigure:FIELD:TARGet` <*field (kG, T)*>

Sets the target 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:TARGet?`

Returns the target 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` <*segment*>,<*rate (A/s, A/min)*>,<*upper bound (A)*>

Sets the ramp rate for the specified segment (values of 1 through the defined number of ramp segments are valid) in units of A/sec or A/min (per the selected ramp rate units), and defines the current upper bound for that segment in amperes (see page 92 for details of the use of ramp segments).

NOTE **The number of ramp rate segments (1-10) is set by the Ramp Segments menu as part of the Misc Setup submenu (see page 158 and page 92).**

• `RAMP:RATE:CURRent:`<*segment*>`?`

Returns the ramp rate setting for the specified segment (values of 1 through the defined number of ramp segments are valid) in units of A/sec or A/min (per the selected ramp rate units) and the current upper bound for that range in amperes. The two return values are separated by a comma. For example:

Sent: `RAMP:RATE:CURRENT:1?`
Returned: `0.1000,50.0000`

• `CONFigure:RAMP:RATE:FIELD` *<segment>,<rate (kG/s, kG/min, T/s, T/min)>,<upper bound (kG, T)>*

Sets the ramp rate for the specified segment (values of 1 through the defined number of ramp segments are valid) in units of kilogauss/second or minute, or tesla/second or minute (per the selected field units and ramp rate units), and defines the field upper bound for that segment in kilogauss or tesla (see page 92 for details of the use of ramp segments). This command requires that a coil constant be defined; otherwise, an error is generated.

• `RAMP:RATE:FIELD:`*<segment>*`?`

Returns the ramp rate setting for the specified segment (values of 1 through the defined number of ramp segments are valid) in units of kilogauss/second or minute, or tesla/second or minute (per the selected field units and ramp rate units) and the current upper bound for that range in kilogauss or tesla (per the selected field units). This command requires that a coil constant be defined; otherwise, an error is generated. The two return values are separated by a comma. For example:

Sent: `RAMP:RATE:FIELD:1?`
Returned: `0.0100,5.0000`

MEASUREMENT COMMANDS AND QUERIES

Included are queries for collecting the present supply current/voltage, magnet field, magnet current, and magnet voltage.

• `VOLTage:MAGnet?`

Returns the magnet voltage in volts. Requires voltage taps to be installed across the magnet terminals and connected to a Magnet Station rear connector.

• `VOLTage:SUPPly?`

Returns the power supply voltage commanded by the Model 430 Programmer in volts.

• `CURRent:MAGnet?`

Returns the current flowing in the magnet in amperes, expressed as a number with a variable number of significant digits past the decimal point (dependent on operating range), such as 5.2320. If the magnet is in persistent mode, the command returns the current that was flowing in the magnet when persistent mode was last entered.

- `CURRent:SUPPly?`

Returns the measured power supply 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 magnet current by the coil constant. If the magnet is in persistent mode, the command returns the field that was present when persistent mode was last entered.

RAMPING STATE COMMANDS AND QUERIES

The ramping state commands control and query the ramping state of the Model 430 Programmer. For more information regarding each state, see page 107.

If the ramping state is commanded remotely, the front panel display and LED indicators will update and accurately reflect the commanded ramping state.

- `RAMP`

Places the Model 430 Programmer in automatic ramping mode. The Model 430 will continue to ramp at the configured ramp rate(s) until the target field/current is achieved.

- `PAUSE`

Pauses the Model 430 Programmer at the present operating field/ current.

- `INCR`

Places the Model 430 Programmer in the MANUAL UP ramping mode. Ramping continues at the ramp rate until the Current Limit is achieved.

- `DECR`

Places the Model 430 Programmer 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 430 Programmer in ZEROING CURRENT mode. Ramping automatically initiates and continues at the ramp rate until the power supply output current is less than 0.1% of I_{max}, at which point the AT ZERO status becomes active.

- `STATE?`

Returns an integer value corresponding to the ramping state according to the table below:

Return Values and Meanings for `STATE?` Query

Return Value	Meaning
1	RAMPING to target field/current
2	HOLDING at the target field/current
3	PAUSED
4	Ramping in MANUAL UP mode
5	Ramping in MANUAL DOWN mode
6	ZEROING CURRENT (in progress)
7	Quench detected
8	At ZERO current
9	Heating persistent switch
10	Cooling persistent switch
11	External Rampdown active

SWITCH HEATER COMMAND AND QUERY

The `PSwitch` commands control and query the state of the persistent switch heater. For further information regarding the persistent switch heater, see section on page 110.

- `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.

- `PERSistent?`

Returns the state of the MAGNET IN PERSISTENT MODE LED on the front panel of the Model 430: “0” if the LED is OFF; “1” if the LED is ON.

QUENCH STATE COMMANDS AND QUERIES

The quench commands control and query the quench state of the Model 430 Programmer. For further information regarding the quench detection functions, see page 120.

- `QUench {0|1}`

Clears or sets the quenched state. Sending a “0” clears any quench condition (equivalent to using the RESET QUENCH front panel SHIFT+3). Sending a “1” sets a quench condition. Setting the quench state to “1” is equivalent to a quench detection by the Model 430 Programmer — the power supply output is forced to 0 V, the quench output of the rear panel Quench I/O connector 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.

- `QUench:COUNT?`

Queries the number of recorded quench events in the non-backup quench event file.

- `QUenchFile?`

Formats and sends the contents of the recorded quench events file as a formatted ASCII text stream. This allows the user to view the state of both the magnet and Model 430 Programmer at each recorded quench event. The output of this query is terminated with two contiguous pairs of <CR><LF> characters (i.e. double terminators).

- `QUenchBackup?`

Formats and sends the contents of the quench events backup file as a formatted ASCII text stream. When the number of recorded quench events reaches 100, the standard quench events file becomes the backup file, and a new (empty) standard quench events file is created. The standard quench events file contains data from the most recent quench events, and the backup file (if it exists) contains data from the 100 quench events preceding the oldest record in the standard quench events file.

The output of this query is terminated with two contiguous pairs of <CR><LF> characters (i.e. double terminators).

NOTE **The `QUenchFile?` and `QUenchBackup?` queries can return thousands of ASCII characters. Ensure your input communicaton buffers are setup to handle a large amount of text.**

RAMPDOWN STATE COMMANDS AND QUERIES

The external rampdown function also has ramp segmenting capability—the function operates in a manner similar to the normal ramp as described on page 60, but the parameters *can only be edited via the remote interface*.

• `CONFigure:RAMPDown:RATE:SEGments` <*# segments*>

Sets the number of external rampdown segments.

• `RAMPDown:RATE:SEGments?`

Returns the number of external rampdown segments.

• `CONFigure:RAMPDown:RATE:CURRent` <*segment*>,<*rate (A/s, A/min)*>, <*upper bound (A)*>

Sets the external rampdown rate for the specified segment (values of 1 through the defined number of rampdown segments are valid) in units of A/sec or A/min (per the selected rampdown rate units), and defines the current upper bound for that segment in amperes.

• `RAMPDown:RATE:CURRent:` <*segment*>`?`

Returns the external rampdown rate setting for the specified segment (values of 1 through the defined number of rampdown segments are valid) in units of A/sec or A/min (per the selected rampdown rate units) and the current upper bound for that range in amperes. The two return values are separated by a comma. For example:

Sent: `RAMPDown:RATE:CURRENT:1?`
Returned: `0.1000,50.0000`

• `CONFigure:RAMPDown:RATE:FIELD` *<segment>*, *<rate (kG/s, kG/min, T/s, T/min)>*, *<upper bound (Kg, T)>*

Sets the external rampdown rate for the specified segment (values of 1 through the defined number of rampdown segments are valid) in units of kilogauss/second or minute, or tesla/second or minute (per the selected field units and rampdown rate units), and defines the field upper bound for that segment in kilogauss or tesla. This command requires that a coil constant be defined; otherwise, an error is generated.

• `RAMPDown:RATE:FIELD:` *<segment>*?

Returns the external rampdown rate setting for the specified segment (values of 1 through the defined number of rampdown segments are valid) in units of kilogauss/second or minute, or tesla/second or minute (per the selected field units and rampdown rate units) and the current upper bound for that range in kilogauss or tesla (per the selected field units). This command requires that a coil constant has been defined; otherwise, an error is generated. The two return values are separated by a comma. For example:

Sent: `RAMPDown:RATE:FIELD:1?`
Returned: `0.0100,5.0000`

• `RAMPDown:COUNT?`

Queries the number of recorded rampdown events in the non-backup rampdown event file.

• `RAMPDownFile?`

Formats and sends the contents of the standard rampdown file as a formatted ASCII text stream. This allows the user to view the state of both the magnet and Model 430 Programmer during each recorded rampdown event. The output of this query is terminated with two contiguous pairs of <CR><LF> characters (i.e. double terminators).

• `RAMPDownBackup?`

Formats and sends the contents of the rampdown backup file as a formatted ASCII text stream. When the number of recorded rampdown events reaches 100, the standard rampdown file becomes the backup file, and a new (empty) standard rampdown file is created. The standard rampdown file contains data from the most recent rampdown events, and the backup file (if it exists) contains data from the 100 rampdown events preceding the oldest record in the standard rampdown file.

The output of this query is terminated with two contiguous pairs of <CR><LF> characters (i.e. double terminators).

NOTE **The** RAMPDownFile? **and** RAMPDownBackup? **queries can return thousands of ASCII characters. Ensure your input communicaton buffers are setup to handle a large amount of text.**

TRIGGER FUNCTIONS

The Model 430 Programmer 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.

DESCRIPTION OF THE TRIGGER FUNCTIONS

The Model 430 Programmer 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 the following table:

Model 430 Programmer Trigger Function Bit Definitions

Bit Number	Bit Name	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	Date and Time	8	The trigger date and time is included in the trigger output in the form *mm/dd/yyyy hh:mm:ss*
4	Supply Current & Voltage	16	Supply current in amperes and supply voltage in volts are included in the trigger output.
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	Ethernet Interface	128	Trigger output data is placed in the Ethernet 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 output. Upon receipt of the `*TRG` command, the Model 430 Programmer places the return data in the appropriate output buffer(s). Data placed in the serial or Ethernet output buffers is transmitted immediately. Note that trigger output data may be placed in both the serial *and* the Ethernet output buffers if desired, but the formatting and output selections are common to both.

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 or serial-to-USB converter is available) connected to the serial interface.**

TRIGGER OUTPUT DATA ORDER

If the trigger output data is not formatted, the data will be comma delimited (i.e. CSV compatible format) and returned in the order of *time*, *magnet field*, *magnet current*, *magnet voltage, and supply current and voltage*. Only the data enabled for output will appear in the trigger output string.

TRIGGER COMMANDS AND QUERIES

- `*ETE` *<enable_value>*

  Enables trigger functions according to the definitions in the table on page 174. 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 tesla):

  ```
  10/23/2007 13:03:14, FIELD= 20.002 T, 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.

ERROR MESSAGES

If an error occurs, the Model 430 Programmer 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.

NOTE **If the Model 430 is emitting error beeps while under remote control, the interface is *not* being used properly and the user risks unintended consequences of failed or ignored commands/ queries. Please contact an authorized AMI Technical Support Representative for assistance if you cannot resolve the issue.**

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 430 Programmer 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 430 Programmer, 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 138). 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.

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 430 Programmer settings on page 125. Be sure to note the field units and ramp units settings and check any unit conversions.

If an Operational Limits Protection Mode is enabled (see section on page 88), ensure the value is below any limits such as ***Ic***.

- `-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 80).

- `-108,"Not ramping"`

The command that was issued requires the Model 430 Programmer to be ramping for the duration of command processing, and the Model 430 Programmer was either not ramping when the command was issued, or stopped ramping before the command processing was completed.

- -109,"N/A in present mode"

The command or query is not applicable to the present operational mode. For example, in Short Sample Mode the commands or queries associated with operation of the Persistent Switch do not apply.

- -110,"Zero inductance"

The command or query is not available due to a zero inductance value in the Load Setup submenu.

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.

- -204,"No recorded events"

There are no events in the request for output of the quench or rampdown standard or backup event files.

EXECUTION ERRORS

- -301,"Heating(Cooling) switch"

The user attempted to initiate a disallowed function during the persistent switch heating or cooling transition period. Ramping functions, for example, are disallowed during the transition period.

- -302,"Quench condition"

The user attempted to change the ramping state while a quench condition was active. A quench condition must be cleared via the RESET QUENCH SHIFT-key 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 on page 139 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.

• `-305,"Supply is off"`

A command was attempted while the "Turn on power supply/Press ENTER to continue" banner is displayed. Commands are disallowed until the banner has been acknowledged.

• `-306,"Rampdown is active"`

No commands are allowed during an active rampdown. All user input is blocked until the rampdown process completes.

• `-307,"Cooled switch @ 0A required"`

A persistent switch current auto-detect cycle requires an initially cooled switch at zero current before initiation.

• `-308,"N/A when persistent"`

Attempted to execute a function that is not available if the magnet is presently in persistent mode.

DEVICE ERRORS

• `-401,"Checksum failed"`

The non-volatile memory which stores the calibration data for the Model 430 Programmer is corrupted. Contact an Authorized AMI Technical Representative for further instructions. Do not continue to use the Model 430 Programmer to operate a superconducting magnet.

• `-402,"Serial framing error"`

The baud rate of the Model 430 Programmer and host device are not identical. The host device must be set to the same baud rate as the Model 430 Programmer (115200).

• `-403,"Serial parity error"`

The number of data bits and/or the parity of the Model 430 Programmer and the host device are not identical. The host device must be set for the same number of data bits, stop bits and parity as the Model 430 Programmer (8 data bits, 1 stop bit and no parity).

- `-404,"Serial data overrun"`

The received buffer of the Model 430 Programmer was overrun. Verify that the host device has hardware handshaking (RTS/CTS) enabled.

- `-405,"File not found"`

The quench or rampdown standard or backup event file was not found.

- `-406,"Corrupted file"`

The quench or rampdown standard or backup even file appears to be corrupted and cannot be read.

- `-407,"Output stream corrupted"`

The quench or rampdown standard or backup event file encountered an error while parsing to ASCII text.

- `-408,"Unknown file format"`

The quench or rampdown standard or backup event file contained an unknown memory format.

NOTE **In the event the quench and/or rampdown event files continue to present an error when queried for output, it is possible to clear the stored history to begin anew.**

For the quench event history this can been done with the *RQC command. The command clears the quench event count and deletes any existing standard and backup quench event files.

The rampdown event history is cleared by the *CRD command. The command clears the rampdown event count and deletes any existing standard and backup rampdown event files.

Service

System Component Routine Maintenance

CAUTION	**Electronic devices are sensitive to electrostatic-discharge (ESD) damage when opened (cover removed). Observe all standard ESD precautions when handling opened power supplies and instruments. Refer to information on page 182.**

The Model 430 Programmer was designed and manufactured to give years of reliable service. The only routine maintenance required is to keep the exterior surfaces of the Model 430 Programmer clean by gently wiping with a damp cloth moistened with a mild detergent.

Model 08150PS Power Supply Routine Maintenance

The Model 08150PS is specifically designed to minimize the need for periodic maintenance, and AMI does not recommend a periodic calibration or service. The cooling method used minimizes the potential for accumulation of dust and dirt within the unit. Keep the exterior surfaces clean by gently wiping with a damp cloth moistened with a mild detergent. The power supply should be occasionally opened for inspection and clean-out of accumulated dust, dirt and debris from ventilation holes, heat sink air passages and circuitry; this is especially important when operating the power supply in dirty or dusty environments. The maintenance interval is dependent on the application and environment; in normal laboratory environments the recommended maintenance interval is two (2) years.

MODEL 601 ENERGY ABSORBER ROUTINE 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 601 should also be kept free of obstructions or excessive dust to allow for proper cooling of the unit.

TROUBLESHOOTING HINTS

The following paragraphs serve as an aid to assist the user in troubleshooting a potential problem with the Model 430 Programmer within a superconducting magnet system. If the user is not comfortable in troubleshooting the system, contact an AMI Technical Support Representative for assistance. Refer to “Additional Technical Support” on page 190.

ELECTROSTATIC DISCHARGE PRECAUTIONS

The Model 430 Programmer system contains components which are susceptible to damage by Electrostatic Discharge (ESD). Take the following precautions whenever the cover of electronic equipment is removed.

1. Disassemble the Model 430 Programmer 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 Model 430 Programmer system 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 desoldering tools.
9. Use only grounded-tip soldering irons.
10. Use only static-dissipative hand tools (pliers, cutters, etc.).

HINTS FOR COMMONLY ENCOUNTERED ERRORS

The following paragraphs provide hints for specific error conditions. Please review the steps for each before beginning a troubleshooting session or contacting an Authorized AMI Technical Support Representative.

THE MODEL 430 DOES NOT APPEAR TO BE ENERGIZED

1. Ensure that the Model 430 Programmer is energized from a power source of proper voltage.

WARNING **If the Model 430 Programmer is 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.**

2. Verify continuity of all line fuses (F1, F2, F3, F4, F5, F6 and F7) located on the Model 430 Programmer printed circuit board.

WARNING **This procedure is to be performed only when the Model 430 Programmer 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 Model 430 Programmer and all connected components are de-energized by first shutting down the system and then 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 Model 430 Programmer top cover and check all fuses for continuity.

   c. If a fuse is bad, replace with a fuse of identical rating:

CAUTION **Installing fuses of incorrect values and ratings could result in damage to the Model 430 Programmer in the event of component failure.**

   d. Replace the fuse and securely fasten the Model 430 Programmer top cover. Reconnect the power-cord.

3. Verify the input voltage selector switch on the Model 430 Programmer 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 Model 430 Programmer. Observe the same safety procedures as presented in step 2, above.

V-V Mode Input Range Picklist Values

Fuse Identification	Fuse Rating	Fuse Size
F1	T 800 mA	5 x 20 mm
F2	T 250 mA	
F3		
F4	T 100 mA	
F5		
F6		
F7		

"Failure to Load" Message Displayed After Power-up

1. Power the Model 430 Programmer off using the front panel power switch.
2. Wait at least 15 seconds.
3. Power the Model 430 Programmer on using the front panel switch.

Power Supply Unstable - Magnet Voltage Oscillates

NOTE **If the size of the voltage oscillation is small (approximately 0.1 volt or smaller), see step 1, below. If the voltage oscillation is larger than approximately 0.1 volt, see steps 1 through 4, below.**

1. Adjust the persistent switch heater current to a value 10 mA larger than the present value. If the oscillation stops, adjust the heater current to as small a value as possible that maintains magnet voltage stability.
2. Verify the power supply controlled by the Model 430 Programmer is configured for remote programming, voltage-to-voltage mode. Consult the manufacturer's operations manual for the necessary power supply configuration.
3. 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 430 Programmer is designed to operate large inductive loads with only relatively small resistive characteristics (i.e. superconducting magnets). The Model 430 Programmer is not designed for use as a general purpose power supply controller for resistive loads.**

4. If the magnet has no persistent switch installed, or has a small inductance (typically less than 3 H), then adjust the stability setting for the Model 430 Programmer. 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 page 76 for more details about the Stability Setting.

THE POWER SUPPLY SYSTEM WILL NOT CHARGE THE MAGNET

1. Verify system interconnecting wiring. If the Model 430 Programmer shows "+0.00 A ↑ Status: Ramping" with the supply voltage, Vs, increasing or at the programmed Voltage Limit (as indicated by the reverse video "V" status indicator), there may be a problem with the power supply. Verify the power supply is on and the program out connection from the Model 430 Programmer to the program voltage input to the power supply is intact.
2. Verify the power leads are properly connected to the magnet.
3. Verify the power supply is configured for remote programming, voltage-to-voltage mode.
4. If the system incorporates the Model 601 Energy Absorber, check the system wiring and verify that the current flow direction through the Model 601 is from the positive (+) to the negative (-) lug.
5. If the system incorporates the Model 601 Energy Absorber, verify that the supplied external DC power converter is connected to the rear of the Model 601, and the AC power cord is also connected to the appropriate power receptacle.
6. If the system incorporates the Model 601 Energy Absorber, check the Voltage Limit settings of the Model 430 Power Supply Programmer and verify the limits are set to a value greater than 5 volts plus the charging voltage and any power lead voltage drops.

CANNOT CHARGE THE MAGNET AT THE SELECTED RAMP RATE

1. Ensure the Model 430 Programmer is properly configured for the connected power supply. See page 70.
2. Ensure that the persistent switch heater is on and the switch heated time has expired. Ramping is disabled during the switch heating period.
3. Check the value of the Voltage Limit. Refer to page 63.

NOTE **If an energy absorber is present in the system, the Model 430 Programmer must command enough power supply voltage to overcome any forward voltage drop due to the energy absorber. Increase the Voltage Limit to account for the +5 VDC 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 oxidized interconnections often exhibit excessive resistances.

CANNOT 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 heated time has expired. Ramping is disabled during the switch heating period.
2. Check the value of the Voltage Limit. Refer to page 63.
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 430 Programmer) is dictating the maximum ramp down rate. An energy absorber is necessary to increase the rampdown rate.

CANNOT CHARGE THE MAGNET TO DESIRED FIELD

1. For *unipolar power supply systems*, 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 negative terminal and the cathode at the positive terminal.
2. Ensure that the Model 430 Programmer supply setup submenu is configured to match the connected power supply, e.g. check that the Model 430 Programmer is configured for the proper voltage-to-voltage programming range according to page 75.
3. If the connected magnet has a persistent switch, verify the switch heater output is properly connected to the Magnet Station connector (see page 191) and the appropriate connector on the cryostat.

CANNOT 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.
2. Ensure the persistent switch cooldown time is adequate (see page 83). Conduction-cooled systems may have much longer switch cooldown periods than wet magnet systems. Optionally use the magnet voltage-based switch transition detection method if the shortest possible cooldown time is an important consideration (see page 82).

CANNOT BRING THE MAGNET OUT OF PERSISTENT MODE

1. If a PSwitch Error was indicated when the PERSIST. SWITCH CONTROL key was used to turn on the persistent switch heater current, then

there is a problem with the wiring to the persistent switch heater. Check the continuity between the persistent switch heater power supply output pins at the rear panel MAGNET STATION CONNECTORS and the connectors on the magnet support stand top plate. Refer to page 192.

2. Verify that the output of the persistent switch heater is set to the appropriate value. Refer to page 105.

3. Ensure that there is sufficient time for the switch to warm before the power supply current is changed. Increase the persistent switch heating time if needed. Refer to page 83.

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 than 4.2K, ensure the magnet is cooled to the temperature specified by the magnet manufacturer.

3. For conduction-cooled magnets, ensure the magnet temperature is proper and in accordance with the magnet manufacturer's specifications.

4. Disable the Model 430 Programmer quench detection feature (see page 121) if you suspect the Model 430 Programmer is falsely indicating a quench condition.

Cannot Lower the Magnet Field

1. Ensure the magnet is not in the persistent mode. Refer to page 114 for the procedure to remove a magnet from the persistent mode of operation.

2. If a PSwitch Error was indicated when the PERSIST. SWITCH CONTROL key was used to turn on the persistent switch heater current, then there is a problem with the wiring to the persistent switch heater. Check the continuity between the persistent switch heater power supply output pins at the rear panel MAGNET STATION CONNECTORS and the connectors on the magnet support stand top plate. Refer to page 192.

The System Current Ramps Slowly from Zero

With the Model 601 Energy Absorber in the system, an initial charging delay will be observed when operating without an inductive load (e.g. a persistent switch is not heated on a connected magnet).

1. To decrease the amount of time delay, increase the ramp rate to 1 A/sec or greater value. Remember to decrease the ramp rate, if necessary, before heating the persistent switch of the connected magnet and attempting to ramp the current.

2. The charging delay will not be observed when operating with an inductive load.

The Model 601 Fault LED Energized with Audible Alarm

1. Verify that the supplied external DC power converter is connected to the rear of the Model 601, and the AC power cord is also connected to the appropriate power receptacle.
2. If the DC power converter is connected properly, observe if an internal green LED is energized by looking through the Model 601 rear-panel grating. If the green LED is energized, then the DC power converter is operating correctly.

   If the internal green LED is not energized, then the DC power converter has failed, or AC power to the DC power converter has been lost. Contact an Authorized AMI Technical Support Representative for a replacement.
3. If the DC power converter is connected and the internal green LED is energized, then the FAULT LED indicates the failure of an internal energy absorbing element. Do not continue to operate the unit and contact an Authorized AMI Technical Support Representative for further instructions.

There is Excessive LHe Boil-off During Operation

Excessive LHe consumption is usually attributable to one or both of the following: 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 page 105.
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.

Cannot Display the Magnetic Field Strength, Only Current

Enter a coil constant in accordance with directions on page 78.

NOTE **Setup menu limits are always required in terms of current.**

CANNOT USE REMOTE COMMUNICATIONS COMMANDS

1. Verify your communications cable integrity and wiring. Refer to page 201 and page 202 for wiring of remote communications connectors.
2. Check to make sure you are sending the correct termination to the Model 430 Programmer. If you are using RS-232, make sure the baud rate, number of stop bits, and data bits/parity settings of the host device are matched to those of the Model 430 Programmer (see page 141). If you are using Ethernet communications, check all Model 430 Programmer network settings (see page 101).
3. Check your host communications software and make sure it is recognizing the return termination characters from the Model 430 Programmer. The return termination characters are *<CR><LF>*.
4. If the Model 430 Programmer is responding repeatedly with errors, try a device clear command (DCL) or powering the Model 430 Programmer off and then back on. Be sure you are sending valid commands.

MAGNET CURRENT DRIFTS UNACCEPTABLY WHILE COOLING PSWITCH

1. Set the PSwitch Cooling Gain to 25% (see page 85) and cool the switch. Observe the current on the front of the Model 430 Programmer while the persistent switch is cooling
2. If the switch will not lock (cool to superconducting), resulting in a PSW lock error, reduce the PSwitch Cooling Gain by several percent and attempt cooling the switch again.
3. If the switch cools but the magnet current has excessive drift during cooling, increase the PSWitch Cooling Gain value by several percent.

MODEL 430 APPEARS TO LOCK UP WHEN CONNECTING TO NETWORK

NOTE **If the IP Address Assignment value is changed, the Model 430 Programmer power must be cycled off and then back on to complete the change.**

On power-up, when connecting via Ethernet (Internet Protocol), the Model 430 will display the firmware version screen until an IP address has been obtained. On busy or slow networks, IP address assignment may take several seconds (even as much as a minute or so on very slow networks). The additional time required may give the temporary false appearance of Model 430 "lockup".

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 web site at:

http://www.americanmagnetics.com

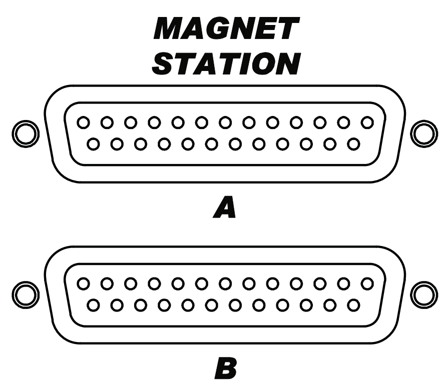
Do not return the Model 430 Programmer or other magnet system components to AMI without prior return authorization.

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

MAGNET STATION CONNECTORS



The two 25-pin D-sub female Magnet Station Connectors are identically wired and connected pin-for-pin internally. Spare connections may be used for custom coil taps or other signals.

NOTE **For maximum noise immunity, use shielded cabling and connect one end of the shield to the Magnet Station Connector shell.**

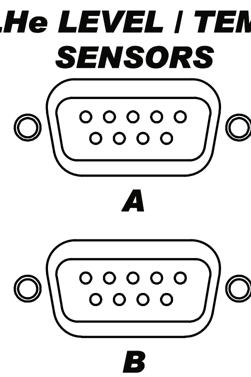
The connectors provide an interface for connecting a *single* integrated instrumentation cable from the magnet support stand to the Model 430 Programmer. The Model 430 Programmer can then be used to distribute the signals to the appropriate instruments or data acquisition systems. The LHe level and temperature sensor signals are also internally routed to the LHe Level / Temp Connectors.

If the Model 430 Programmer is purchased as part of a magnet system, a Magnet Station Connector instrumentation cable will be provided with the system.

Magnet Station Connectors Pin Definitions

Pin	Function	Pin	Function
1	LHe Sensor I+ (Red)	14	spare
2	LHe Sensor I– (Black)	15	spare
3	LHe Sensor V– (Yellow)	16	spare
4	LHe Sensor V+ (Blue)	17	spare
5	Temperature Sensor I+ (Red)	18	spare
6	Temperature Sensor I– (Black)	19	spare
7	Temperature Sensor V– (Yellow)	20	spare
8	Temperature Sensor V+ (Blue)	21	spare
9	Persistent Switch Heater I+ (Red)	22	spare
10	Persistent Switch Heater I– (Black)	23	spare
11	Magnet Voltage Tap V+ (Yellow)	24	spare
12	Magnet Voltage Tap V– (Blue)	25	spare
13	spare		

LHe Level / Temp Connectors



LHe Level / Temp Connectors Pin Definitions

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 LHe Level / Temp Connectors are identically wired and connected pin-for-pin internally.

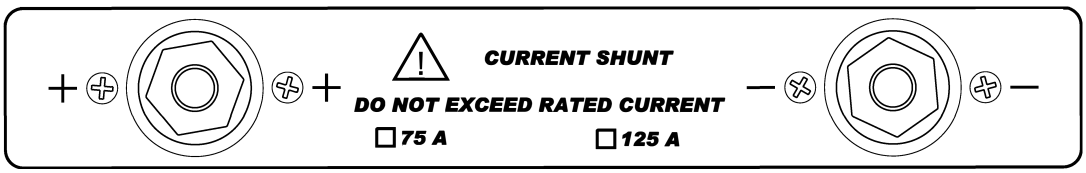
WARNING

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).

The connectors route the incoming signals from the Magnet Station Connectors to external level and/or temperature instruments. If an AMI Liquid Level Instrument is purchased (with LHe measurement option) with the Model 430 Programmer and magnet system, an LHe level cable will be provided.

NOTE **For maximum noise immunity, use shielded cabling and connect one end of the shield to the LHe Level / Temp Connector shell.**

PROGRAMMER SHUNT TERMINALS



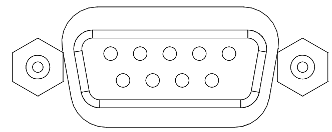
The shunt terminals should be connected so that positive conventional current flows from the + terminal to the – terminal. Refer to the Installation section beginning on page 23 for a detailed description of the system interconnections for a specific system configuration.

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.**

CAUTION **Do not overtighten the nuts on the shunt terminals of the Model 430 Programmer (refer to specifications in the table on page 18). Overtightening can result in damage to the terminals.**

CURRENT TRANSDUCER CONNECTOR

CURRENT TRANSDUCER



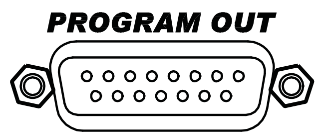
CAUTION **Operating the system without the connection between the Model 430 and the current transducer (CT) can result in loss of control, and may damage the CT.**

The current transducer connector, which is only present for the High-Stability Option or systems with a maximum current greater than 250 A, provides pins for connection of the external current transducer (CT) to the Model 430 Programmer. Power to the CT is also provided via this connector. The connector is a 9-pin D-sub female connector with the shell lugs connected to the Model 430 Programmer chassis ground.

Current Transducer Connector Pin Definitions

Pin	Function
1	Sense Out –
2	not used
3	not used
4	Power Input: 0 VDC (common)
5	Power Input: –15 VDC
6	Sense Out +
7	not used
8	not used
9	Power Input: +15 VDC

PROGRAM OUT CONNECTOR



Program Out Connector Pin Definitions

Pin	Function	Pin	Function
1	not used	9	not used
2	not used	10	not used
3	not used	11	Program Out Voltage
4	Program Out Common	12	not used
5	not used	13	not used
6	not used	14	not used
7	not used	15	not used
8	not used		

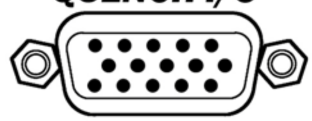
The Program Out 15-pin D-sub male connector provides up to a –10 VDC to +10 VDC output designed to drive the remote *voltage-to-voltage* programming input of a connected power supply.[1] Refer to “Installation” on page 23 for a detailed description of the system interconnections. Pin 11 of the Program Out connector is the program out voltage. Pin 4 of the Program Out connector is the output return. All other pins of the Program Out connector are unused.

NOTE **For maximum noise immunity, the Model 430 Programmer 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.**

1. The *optional* Short-Sample Mode operates the connected power supply in voltage-to-current mode. See page 233.

QUENCH I/O CONNECTOR

QUENCH I/O



The Quench I/O connector provides pins for external quench detection input, external rampdown input, quench detection output, and several other Model 430 status output signals (refer to the table below). The Quench I/O connector is a high density 15-pin D-sub male connector. The shell lugs of the connector are connected to the Model 430 Programmer chassis ground.

Quench I/O Connector Pin Definitions

Pin	Polarity	Function
1	n/a	Quench Output (Model 430 Programmer NO dry contacts)
2		
3	n/a	Relay K3 Output (Model 430 Programmer NO dry contact - see Pin 8)
4	circuit common	Quench Input (customer-suppled external NO dry contacts) **NOTE:** The Model 430 has a 1K Ohm pull-up resistor for this input.
5	+	
6	circuit common	External Rampdown Input (customer-supplied external NO dry contact) **NOTE:** The Model 430 has a 1K Ohm pull-up resistor for this input.
7	+	
8	n/a	Relay K3 Output (see Pin 3)
9	n/a	Magnet Energized Relay (K2) Output (Model 430 Programmer NO dry contacts)
10		
11	n/a	At Target Relay (K4) Output (Model 430 Programmer NO dry contacts)
12		
13	n/a	Leads Energized Relay (K5) Output (Model 430 Programmer NO dry contacts)
14		
15	n/a	Future input (not used)

External Quench Detection Input

The external quench detection input allows the user to facilitate his own quench detection circuitry, the output of which is wired to the Model 430 Programmer. The external input overrides the internal quench detection function of the Model 430 Programmer and cannot be disabled.

CAUTION **The external quench detection input is a dry contact input, not galvanically isolated from the Model 430 Programmer internal circuitry. To avoid noise problems and potential damage to the Model 430 Programmer, it is very important that the dry contacts to which the input is connected be galvanically isolated from any external circuitry.**

It is recommended that the external quench detection input be driven by the contacts of a low level dry contact relay, which will galvanically isolate the input from all other circuitry.

When the external quench detection input pins (pins 4 and 5 of the Quench I/O connector) are shorted together, it is the same as if an Model 430 Programmer internal quench detection occurred. Refer to page 120 for details.

NOTE **The Model 430 Programmer takes approximately 600 microseconds from the time it detects the external quench input to execute the quench condition process. Refer to page 121 for more information.**

External Rampdown Input

When enabled[2], the external rampdown input initiates a rampdown of the magnetic field of the magnet when triggered.

CAUTION **The external rampdown input is a dry contact input, not galvanically isolated from the Model 430 Programmer internal circuitry. To avoid noise problems and potential damage to the Model 430 Programmer, it is very important that the dry contacts to which the input is connected be galvanically isolated from any external circuitry.**

It is recommended that the external rampdown input be driven by the contacts of a low level dry contact relay, which will galvanically isolate the input from all other circuitry.

When the external rampdown input pins (pins 6 and 7 of the Quench I/O connector) are shorted together for more than 10 milliseconds, the Model 430 Programmer enters external rampdown mode. If the magnet

2. Refer to “Enable External Rampdown” on page 91.

is in driven mode, the Model 430 Programmer ramps the magnet field/current to zero. If the magnet is in persistent mode, the Model 430 Programmer ramps the power supply to match the last known persistent magnet current, turns on the persistent switch heater, waits the specified heated time (or detects the transition using the magnet voltage per the *PSwitch Transition* setting[3]) and then ramps the magnet field/current to zero.

This function may be used with the AMI Model 1700 Liquid Level Instrument[4]. The level instrument has a NO relay associated with the low level condition and this contact closure can be connected to the External Rampdown Input so that when a low helium level occurs in a system, the magnet is safely and automatically ramped down, preventing a magnet quench. AMI offers a cable for this purpose or the user can make a suitable cable to connect pins 5 and 6 of the Aux I/O connector of the Model 1700 instrument to pins 6 and 7 of the 430 Programmer, Quench I/O connector.

CAUTION **The separate external segmented-rampdown option described below ignores the Voltage Limit during the rampdown process.**

NOTE **If the number of external-rampdown ramp segments is set to zero, the modified rampdown is not used and the standard ramp rate table will be effective during external rampdown. The Model 430 Programmer defaults to an empty rampdown table (number of segments equal zero).**

A separate, optional segmented-ramp-rate table is available for external rampdown. This option is accessible only via the external interface commands (see page 165).

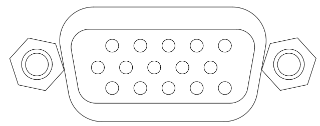
EXTERNAL QUENCH DETECTION OUTPUT

The external quench detection output is a set of dry contacts (pins 1 and 2 of the Quench I/O connector) which *close* when the Model 430 Programmer internal circuitry detects a quench condition. Note that the Model 430 Programmer internal quench detection must be enabled to assure that the Model 430 Programmer will indicate a detected quench (see page 86).

The contacts remain shorted (when a quench has been detected) until the RESET QUENCH SHIFT-key is used to clear the quench condition.

3. See page 82.
4. Or the Model 13x series of Liquid Helium Level Instruments for legacy systems.

AUXILIARY INPUTS CONNECTOR



The Aux Inputs connector provides pins for external voltage inputs, reserved for future use. The shell lugs of the connector are connected to the Model 430 Programmer chassis ground. The Aux Inputs connector is a high density 15-pin D-sub female connector.

Aux Inputs Connector Pin Definitions

Pin	Function	Pin	Function
1	Aux Input 1 + (Vm +)[a]	9	Aux Input 4 –
2	Aux Input 1 – (Vm –)	10	not used
3	Aux Input 2 + (Vss +)[b]	11	Aux Input 5 +
4	Aux Input 2 – (Vss –)	12	Aux Input 5 –
5	not used	13	Aux Input 6 +
6	Aux Input 3 + (Tmax +)[c]	14	Aux Input 6 –
7	Aux Input 3 – (Tmax –)	15	not used
8	Aux Input 4 +		

a. Auxiliary Input 1 is consumed by the magnet voltage input internally connected to the Magnet Station connector (pins 11+ and 12–) for *Model 430 units that ship with version 3.00 firmware or later.* It is used for the magnet voltage-based switch transition detection logic and is not available for general use. See page 82 for more information.

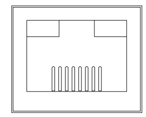
b. Auxiliary Input 2 is used for the sample voltage taps (Vss) for the optional Short-Sample operational mode. See page 233 for more information.

c. Auxiliary Input 3 is optionally used for the Tmax 0 to 10VDC signal from an external temperature monitor. See page 90 for more information.

Each input pin has a 1 megohm resistor to analog circuit common. The inputs are differential inputs. Aux Input 1 and Aux Input 2 have a ± 1 V nominal input voltage range. Aux Input 3, Aux Input 4, Aux Input 5 and Aux Input 6 have a ±10 V nominal input voltage range.

ETHERNET CONNECTOR

ETHERNET



The Ethernet connector provides visual (LED) indications of the status:

1. Steady green when a link is established.
2. Blinking amber for network activity as network packets are received or transmitted.

Ethernet RJ-45 Connector Pin Definitions

Pin	Mnemonic	Function
1	TXD+	Transmit differential output +
2	TXD–	Transmit differential output –
3	RXD+	Transmit differential input +
4	not used	
5		
6	RXD–	Transmit differential input –
7	not used	
8		

RS-232 CONNECTOR

The RS-232 connector is a standard DTE 9-pin D-sub male connector

RS-232 Connector Pin Definitions

Pin	Mnemonic	Function
1	DCD	Data Carrier Detect
2	RXD	Receive Data
3	TXD	Transmit Data
4	DTR	Data Terminal Ready
5	GND	Signal Ground
6	DSR	Data Set Ready
7	RTS	Request To Send
8	CTS	Clear to Send
9	RI	Ring Indicator

PC (DB9)-to-Model 430 RS-232 Cable Connections

PC (DTE) DB9 Pin	**Model 430 (DTE)** DB9 Pin
1, 6	4
2	3
3	2
4	6, 1
5	5
7	8
8	7

ABBREVIATIONS AND ACRONYMS USED IN THIS MANUAL

Abbreviations and Acronyms

Term	Meaning
AC; ac	Alternating Current; strictly, electrical *current* that periodically reverses direction. Typically used also to describe an electrical power source in terms of the *voltage*. For example, 240 VAC.
ASCII	American Standard Code for Information Interchange; numerical representation of characters such as 'a' or '@' or an action (such as line-feed); 'plain' raw text with no formatting such as tabs, bold or underscoring
<CR>	Text carriage-return (\r) character
CT	Current Transducer
CTS	DTE clear-to-send signal
DB9	Type of electrical connector containing 9 pins arranged in two parallel rows of 4 pins and 5 pins each)
DB15	Type of electrical connector containing 15 pins arranged in two parallel rows of 7 pins and 8 pins each
D-Sub	Term referring to the family of connectors containing an odd number of pins in two parallel rows with a 1-pin difference in pins-per-row (DB9, DB15, and DB25 are most common)
DC; dc	Direct Current; strictly, electrical *current* that flows in only one direction. Typically used also to describe an electrical power source in terms of the *voltage*. For example, 12 VDC.
DCE	Data Communication Equipment: The devices of a communications network, such as modems, that connect the communication circuit between the data source and destination (DTE’s).
DHCP	Dynamic Host Configuration Protocol; a computer networking protocol which dynamically distributes the IP address to networked devices
di/dt	Current flow rate of change
DSP	Digital Signal Processing; digital representation and processing of signals typically converted to/from analog signals external to the processor.
DTE	Data Terminal Equipment: the source or destination of data in a communication connection. DTE’s are connected to DCE which in turn is connected to the communication channel.
EFT	Electrical Fast Transient
EMC	Electromagnetic Compatibility
E_o	Power supply output voltage

Abbreviations and Acronyms (Continued)

Term	Meaning
ESD	Electrostatic Discharge
FIFO	First-in / First-out
FTP	File Transfer Protocol
i, I	Electrical current flow
Ic, I_c	Critical current, the maximum recommended current for at a given superconductor temperature
I_o	Power supply output current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
I/O	Input/Output; The hardware and associated protocol that implement communication between information processing systems and/or devices. Inputs are the signals or data received by the system or device, and outputs are the signals or data sent from it.
IP	Internet Protocol; when used with “address”, refers to a numerical internet address
IR	The product I x R: the voltage developed by electrical current flow (I) through a resistance (R)
kG	kilogauss: a magnetic field unit of measurement
L	Electrical circuit inductance measured in henries; superconducting magnets act as nearly perfect inductors when at superconducting temperatures.
LED	Light-Emitting Diode; a semiconductor device that emits light when energized - used for visual status indication
<LF>	Text line-feed (\n) character
LHe	Liquid helium
LN2	Liquid nitrogen
Max	Maximum
Min	Minimum
ms, msec	Milli-seconds
nom	Nominal
P/S	Persistent switch; a switch which, if perfectly realized, has zero resistance when at superconducting temperatures. An integrated heater element allows the switch to be heated for purposes of charging or discharging a superconducting magnet.
pk	Peak
PSw	Persistent switch

Abbreviations and Acronyms (Continued)

Term	Meaning
PSwitch	Persistent switch
RF	Electromagnetic radiation in the radio frequency spectrum
R_{lead}	Electrical circuit lead or wiring resistance
RTS	DTE ready-to-send signal
RS-232	RS-232 is a long-established standard and protocol for relatively low speed serial data communication between computers and related devices; originally established for teletypewriter communication.
SCPI	Standard Commands for Programmable Instruments
STP	Standard Temperature and Pressure
T	Tesla: a magnetic field unit of measurement = 10 kilogauss
Temp	Temperature
V	Volts
V-I	Voltage-controls-Current; the power supply mode in which the Program Out voltage is in direct ratio to the output current of a connected power supply; used for Short-Sample mode by the Model 430 Programmer.
V-V	Voltage-controls-Voltage; the power supply mode in which the Program Out voltage is in direct ratio to the output voltage of a connected power supply; used by the Model 430 Programmer for superconducting magnet operation.
VA	Volt-amperes (V x I); a unit of electrical reactive power
VFD	Vacuum Fluorescent Display; an electronic display device which, unlike liquid crystal displays, can emit very bright, high contrast light in various colors.
V_{lead}	Voltage (i x R) developed across circuit lead or wiring resistance due to high current flow
V_m	Magnet voltage
V_s	Power supply voltage
V_{ss}	Short-sample voltage

POWER SUPPLY DETAILS

This section provides the technical details of the individual power supply component of the AMI Bipolar Power Supply Systems.

WARNING **All power supply parameters, both hardware and software, have been set by AMI, and no field adjustments or reconfiguration of the power supply should be attempted in the field.**

Service must be referred to authorized personnel. Using the power supply in a manner not specified by AMI may impair the protection provided by the power supply. Observe all safety precautions noted throughout this manual.

NOTE **These individual power supply unit details are provided for reference only. Some of the basic power supply parameters given in this section may not apply as configured by the factory in the closed loop current feedback configuration (incorporating the Model 601 Energy Absorber) under control of the AMI Model 430 Programmer.**

An AMI Model 430 Power Supply Programmer, one or more Model 08150PS Power Supplies, and one or more Model 601 Energy Absorbers are configured to make up the AMI Bipolar Power Supply Systems. The Model 08150PS operates in the 05120PS, 05240PS, 05360PS, and 05600PS configuration as a +10 VDC, +120 A, unipolar, voltage and current stabilized DC supply (introduction of the Model 601 Energy Absorber reduces the available load voltage range to ±5 VDC but provides for bipolar operation).

Multiple Model 08150PS power supplies may be connected in a parallel or series configuration to provide the rated current and operating under the control of the Model 430 Power Supply Programmer.

SINGLE UNIT SPECIFICATIONS

Model 08150PS Power Supply Specifications

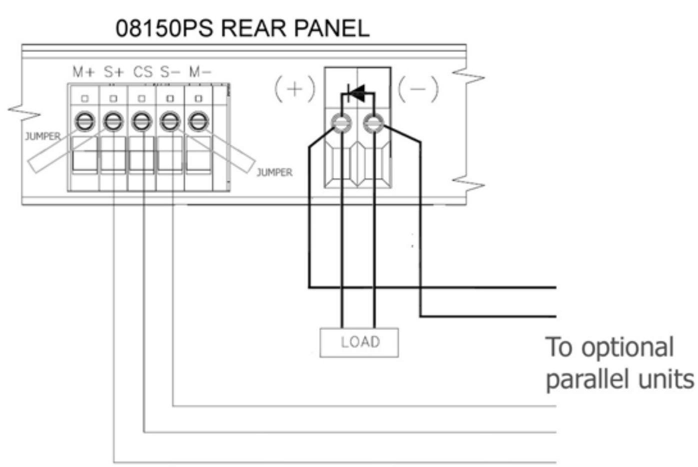
Specification		Rating / Description	Condition
INPUT CHARACTERISTICS			
Voltage (AC)	nominal	110-240 VAC	Single Phase.
	range	100-255 VAC	Wide Range; contact AMI for operation to 265 VAC.
Voltage (DC)	range	125-420 VDC	No regulatory agency approval.
Frequency	nominal range	50-60 Hz	
	maximum	45-440 Hz	Increased Leakage above 66 Hz.
Power Factor	typical	0.99	Meets EN 61000-3-2.
Maximum Input Current	120 VAC	13A RMS	Rated load (1200W).
	240 VAC	6.5A RMS	
Inrush Current	265 VAC	40A	Peak
	132 VAC	20A	
Input Fusing		Circuit Breaker	2-line
Low ac Protection		Self protected	No fixed limits.
Output hold up	typical	10 milliseconds	Ride through.
Leakage Current	115 VAC, 60Hz	5mA max	
	230 VAC 50Hz	10mA max	
OUTPUT CHARACTERISTICS			
Voltage (dc)	range	0 to +8 VDC	1200 W (current limited to 150 A)
Current (dc)	range	0 to +150 A	1200 W (voltage limited to 8 VDC)
Voltage (dc)	range	0 to +10 VDC	1200 W (current limited to 120 A)
Current (dc)	range	0 to +120 A[a]	1200 W (voltage limited to 10 VDC)
Type of stabilizer		CV/CC	Voltage/Current
Adjustment range	voltage	0-100% of rated voltage	No minimum load required.
	current	minimum to 100% of rated current	
Source effect	voltage	0.01% E_{max}	Over full source range.
	current	0.01% I_{max}	
Load effect	voltage	0.01% E_{max}	Over full load current range.
	current	0.02% Imax	
Temperature effect	voltage	0.02%/deg C	0-50 deg C
	current	0.05%/deg C	
Time effect (drift)	voltage	0.05%/24hr	After 30 min warmup.
	current	0.05%/24hr	
Error sensing		0.25 volts per wire	Above rated output. Contact AMI for larger margins.
Isolation voltage		600 VDC or peak	Either output terminal to ground.
Transient recovery for load change	excursion	1% of E_{max}	50% load step 2A/microsecond max.
	recovery	2 msec	Return to 0.1% of setting.
Turnon/turnoff overshoot		same as load transient response limits	
Overvoltage protection	voltage	120% of E_{max}	
Overcurrent protection	current	120% of I_{max}	

Model 08150PS Power Supply Specifications (Continued)

Specification		Rating / Description	Condition
Overtemperature protection		Shutdown	
Open Load wire protection		Shutdown	
Parallel operation		Active load sharing	Up to 5 units, maximum.
GENERAL (ENVIRONMENTAL) SPECIFICATIONS			
Temperature	operating	–20 to +50 deg C	Rated load. Derate at 25W per °C between 50 and 70°C.
	storage	–40 to +85 deg C	
Cooling		3 internal DC fans	exhaust to the rear
Humidity		0 to 95% RH	non-condensing
Shock		20 g, 11msec ±50% half sine	non-operating
Vibration	5 -10 Hz	10mm double amplitude	3-axes, non-operating
	10-55 Hz	2g	
Altitude		sea level to 10000 ft.	0-3,000 ft: 100%, linear derating to 70% of power at 10,000ft.
Dimensions	English	1.735"H x 19"W x 17.5"D	Depth excluding connectors and terminal blocks.
	metric	44.45 x 482.6 x 443.7 mm	
Weight	English	15 lbs	
	metric	6.82kg	
Source power connector		IEC 320-C19 appliance inlet	250 VAC, 16A (VDE); 125 VAC, 20A (UL)
Load connections		Nickel plated copper busbars	Provision for safety covers.
Analog programming port.		15 pin D-sub	

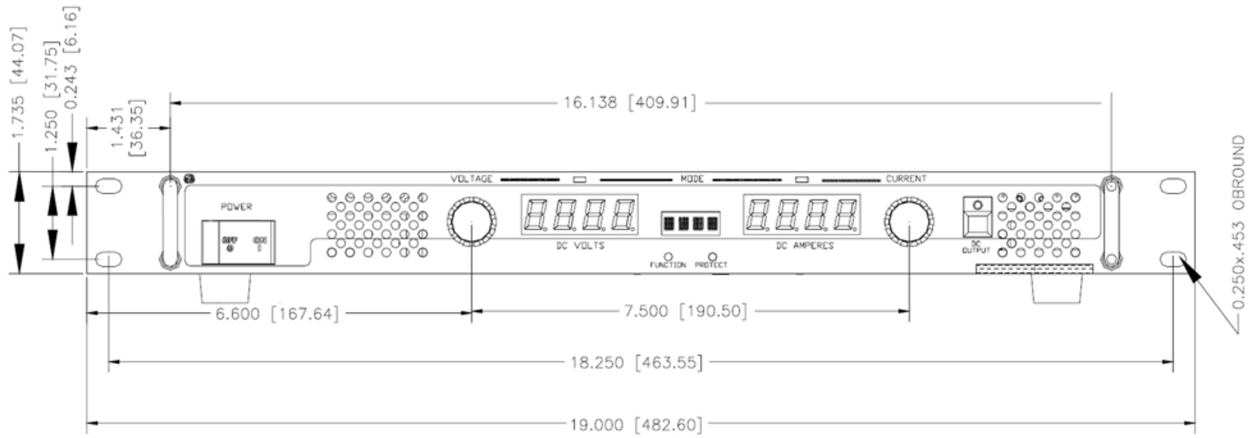
a. Current limited to 100 Adc (1000 W) per power supply unit by AMI system configuration.

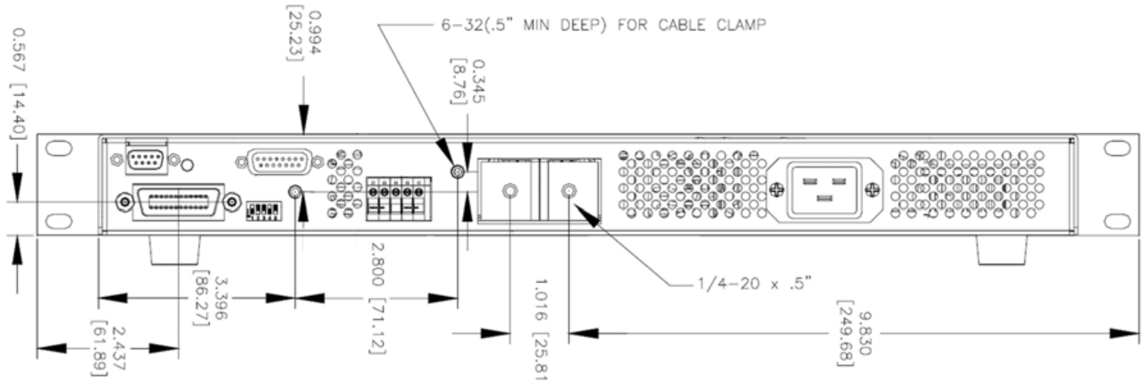
The figure below shows the Model 08150PS rear panel terminal block connections,



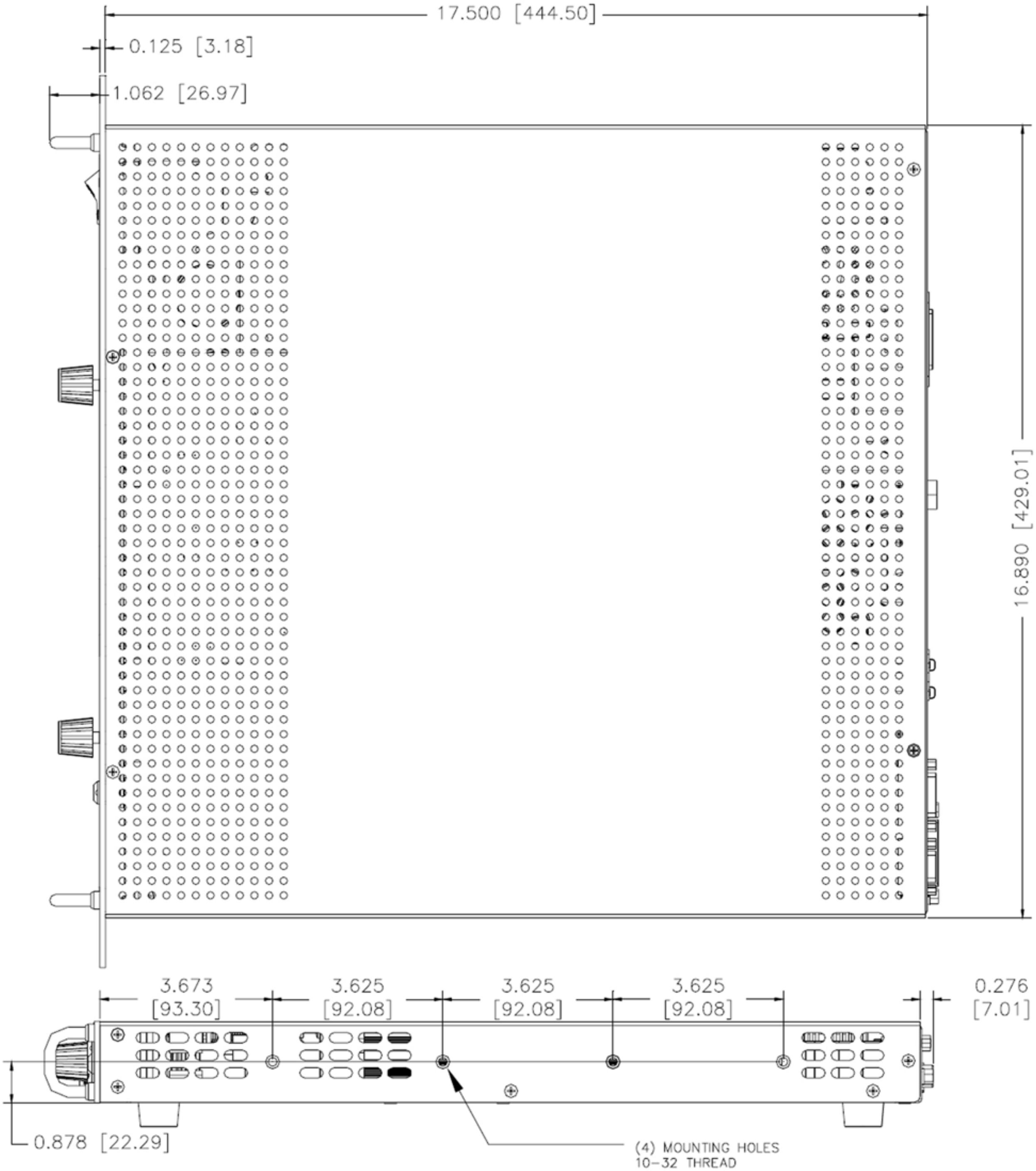
Model 08150PS Terminal Block Connections

SINGLE SUPPLY DIMENSIONS





Model 08150PS Dimensions - Front and Rear Views



Model 08150PS Dimensions - Top and Side Views

ENERGY ABSORPTION

In order to provide magnet discharge current control with a unipolar power supply, AMI introduces the Model 601 Energy Absorber into the current loop (refer to “Dual-Quadrant Operation” on page 20 and Figure on page 73).

MODEL 601 SPECIFICATIONS

The AMI Model 601 Energy Absorber is designed to provide a compact, fast-rampdown option of up to –5 VDC for AMI power supply systems. The Model 601 is designed to operate safely in the event of loss of facility ac power by drawing the necessary power for internal cooling from the superconducting magnet. Upon loss of facility AC power to a power supply system, the Model 601 will ramp the system to zero current at a discharge rate of approximately –5 VDC.

Model 601 Energy Absorber Specifications

Parameter	Value
AC Input (to AC power adapter)	100 to 240 VAC ± 10%, 50/60 Hz, 100 VA max
DC Input (from AC power adapter)	5 VDC ± 5%, 4 A max
Maximum Magnet Operating Current	130 A @ 25°C, derated linearly to 100 A @ 40°C
Nominal Discharge Voltage	5.0 VDC ± 2%
Discharge Voltage Temperature Coefficient	± 150 ppm / °C max
Internal Series Resistance[a]	2 mΩ ± 1 mΩ
Rated Operating Temperature	0 to 40°C @ 100 A, 0 to 25°C @ 130 A
Rated Operating Relative Humidity	0 to 95% non-condensing
Torque Limit on Current Terminals	48 lbf-in.

a. Nominally adds 200 mV voltage drop at 100 A

CONNECTING MULTIPLE MODEL 601 ENERGY ABSORBERS

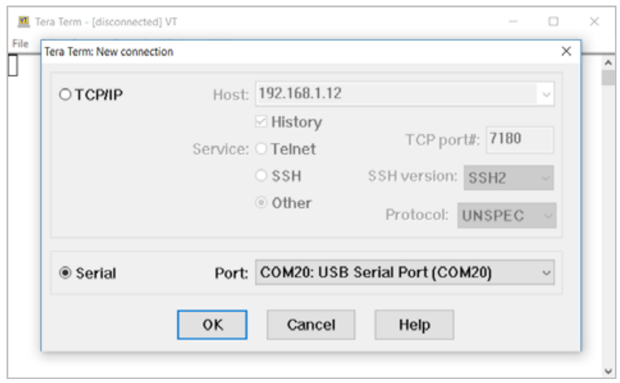
The AMI Bipolar Power Systems incorporate one or more Model 601 units operated in parallel. The positive (+) and negative (–) lugs for multiple units are ganged together using conductive bus bars. The power leads, from the supply and to the magnet, may be connected to any mounting lug if an additional lug is not provided in the bus bar.

In addition to the ganged lugs, the coaxial connectors on the rear of each Model 601 must all be connected together with coaxial cables — no BNC terminators should be used. Use standard BNC “T” adapters on the inner units.

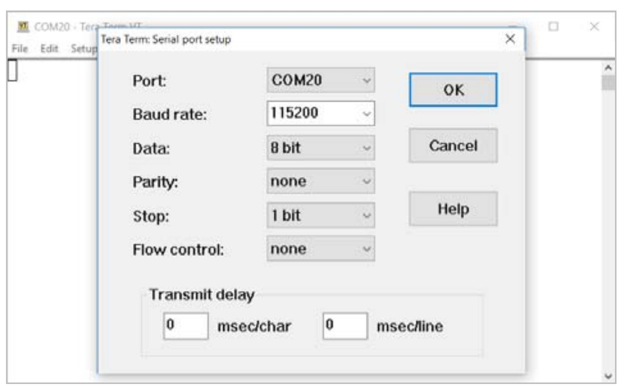
REMOTE COMPUTER COMMUNICATION WITH THE MODEL 430

COMMUNICATION VIA RS-232

1. Using serial null modem adapter (and possibly a gender changer)[5], connect the DB9 RS-232 connector on the rear of the Model 430 Programmer to a standard USB-to-serial cable[6] connected to a computer.
2. Start a terminal emulator program on the remote computer. As an example, this procedure will use the open-sourced Tera Term program[7] running on a Windows machine. You are greeted immediately with the *Tera Term New Connection* dialog.

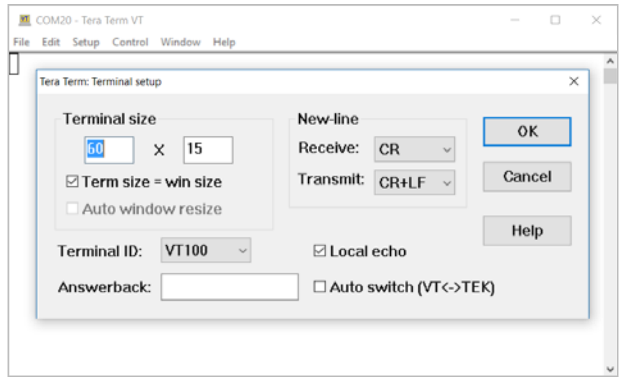


3. Choose the *Serial* option and then the *Port* to which the Model 430 is connected. This example illustrates *COM20: USB Serial Port (COM20)*, which in this example is the port assigned by Windows to a USB-to-serial adapter cable. Press *OK*.
4. Use the *Setup* | *Serial Port...* menu command in Tera Term to show the serial parameters dialog. Set the parameters as shown at right per page 141 (*Port* selection is specific to your setup).



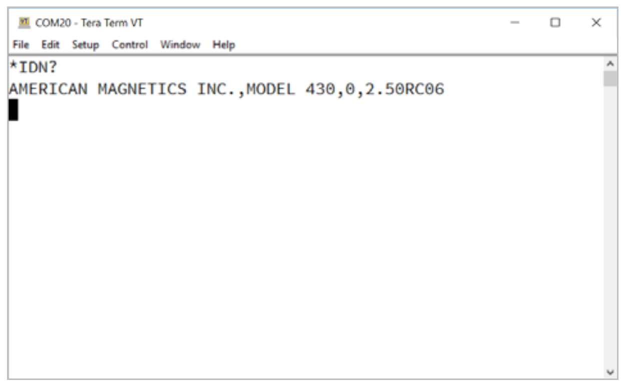
5. Mouser Electronics offers a compact null-model/gender changer: see part # 515-140-448-R.
6. AMI recommends FTDI USB-to-serial cables. See DigiKey part # 768-1084-ND.
7. The Tera Term application is open-sourced and is available at https://ttssh2.osdn.jp/index.html.en. A Windows installer for a *recent* version (not guaranteed to be the latest) is also included on the internal Model 430 web page, see page 230.

5. Use the *Setup* | *Terminal...* command in Tera Term to show the terminal setup parameters. Set the parameters as shown at right. You may choose the *Terminal size* per your preference and screen size.

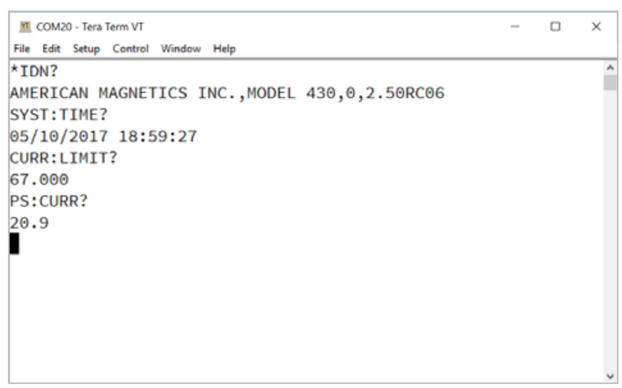


6. Optionally choose the *Setup* | *Save Setup...* menu selection in Tera Term to save these settings as the default for new sessions. Depending on where you install Tera Term, you may need to specify a different *Setup directory* depending on your account privileges.

7. Type *IDN? followed by *Enter* to test the connection. The Model 430 Programmer should respond with “AMERICAN MAGNETICS, INC., MODEL 430,X,Y.Y” where X is the serial number and Y.Y is the firmware version.



8. Issue commands or queries as desired. See “Remote Interface Reference” on page 127.



COMMUNICATION VIA ETHERNET

1. Connect the Model 430 Programmer RJ-45 Ethernet port either directly to a host computer or through a computer network on which the host computer resides:
   a. For a host computer on a network, connect a standard Ethernet cable between the Model 430 and the network.
   b. For a direct hardwired connection between the Model 430 and a host computer, use a “null-modem” or “crossover” Ethernet cable connected from the Model 430 directly to the host computer.

NOTE **Most modern computers will negotiate the direct connection cross-over automatically with a standard Ethernet cable.**

2. Turn on the Model 430 and press ENTER at the “Turn on power supply . . .” prompt.
3. Press ***MENU*** to enter the menu system.
4. Use <◄>/<►> to navigate to the *Net Settings* submenu and press ENTER.
5. Use <◄>/<►> as necessary to navigate to *Addr Assignment (Present)*.

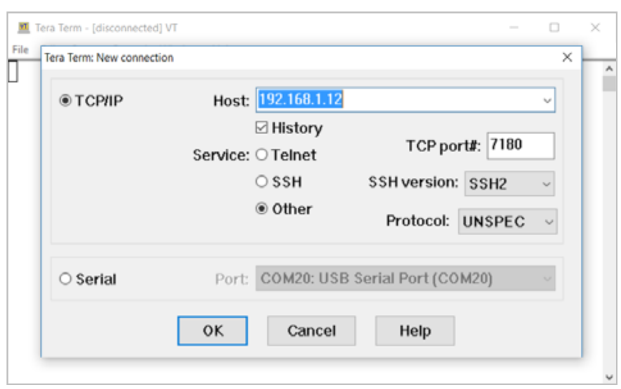
NOTE **The Addr Assignment (Present) must show “DHCP” as originally set by AMI.**

NOTE **In the following step, the IP Address is the four part number separated by periods (.), and will change with each Ethernet connection.**

6. Use <◄>/<►> to locate *IP Address (Present)*, similar to that shown below:

```
0.00 A   -   IP Address (Present)
0.00 Vs      192.168.1.12 (DHCP)
```

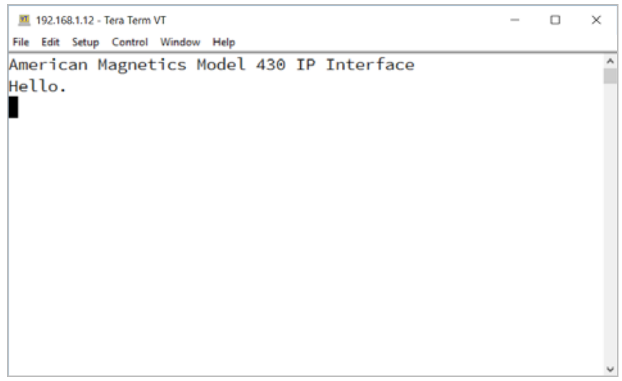
7. Make note of the *IP Address (Present)*.
8. Start a terminal emulator program on the remote computer. As an example, this procedure will use the open-sourced Tera Term program[8] running on a Windows machine. You are greeted immediately with the *Tera Term New Connection* dialog.



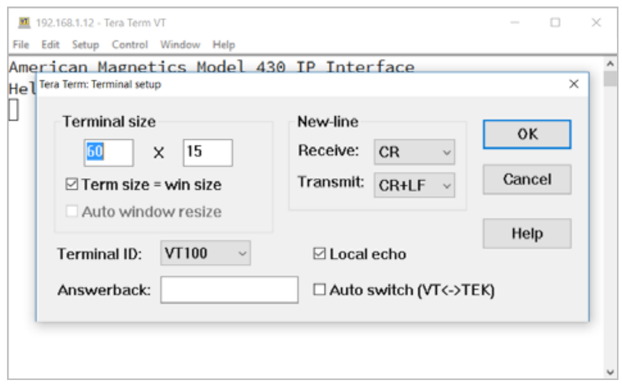
9. Choose the *TCP/IP* option and then the *Host* address for the Model 430 that was determined from the previous Step 7. This example illustrates

192.168.1.12. Choose the *Service* | *Other* and enter *TCP port #* 7180. Press *OK*.

10. The computer will connect with the Model 430 Programmer and display the welcome message.

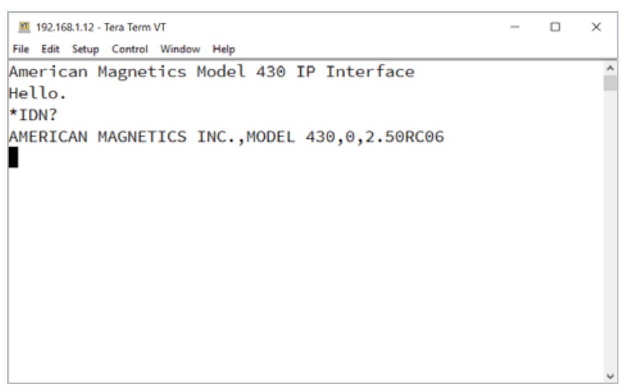


11. Use the *Setup* | *Terminal...* command in Tera Term to show the terminal setup parameters. Set the parameters as shown at right. You may choose the *Terminal size* per your preference and screen size.



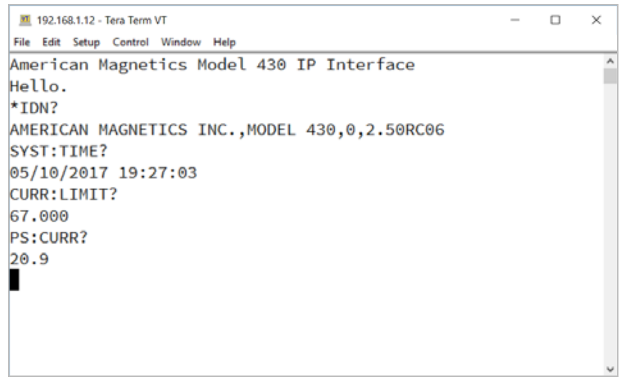
12. Optionally choose the *Setup* | *Save Setup...* menu selection in Tera Term to save these settings as the default for new sessions. Depending on where you install Tera Term, you may need to specify a different *Setup directory* depending on your account privileges.

13. Type *IDN? followed by *Enter* to test the connection. The Model 430 Programmer should respond with “AMERICAN MAGNETICS, INC., MODEL 430,X,Y.Y” where X is the serial number and Y.Y is the firmware version.



8. The Tera Term application is open-sourced and is available at https://ttssh2.osdn.jp/index.html.en. A Windows installer for a *recent* version (not guaranteed to be the latest) is also included on the internal Model 430 web page, see page 230.

14. Issue commands or queries as desired. See “Remote Interface Reference” on page 127.



UPGRADING THE MODEL 430 FIRMWARE VIA FTP

NOTE **IMPORTANT If the Model 430 is being upgraded from Version 1.59 or earlier, proceed to the upgrade procedure in section on page 225.**

NOTE **These instructions apply specifically to the Microsoft Windows operating system. For other operating systems, please make adjustments as appropriate.**

HARDWARE AND SOFTWARE REQUIREMENTS

1. Personal Computer (PC) networked by Ethernet to the system on which the target Model 430 resides,
   or
   PC connected directly to the target Model 430 via a "null-modem" or "cross-over" Ethernet cable.

NOTE **Most modern computers will negotiate the direct connection cross-over automatically with a standard Ethernet cable.**

2. The Model430.exe upgrade file extracted from the zip file (typically of the same name) provided by AMI.
3. FileZilla[9] or other appropriate FTP Client installed on the PC. For this procedure an open-source FTP client called FileZilla is illustrated.

   Also included is an alternative upload procedure using the command-line interface of the built-in Windows FTP client that requires no software installation (see page 224).

PREPARATION

1. Install FileZilla or another appropriate FTP Client on the PC that will used for the upgrade.
2. The AMI Model 430 can be upgraded through a file server, or similar network, or via direct Ethernet connection to the PC:

   a. Via Network:

      (1.) Make a new "Upgrade" folder located in an appropriate location on the file server.

      (2.) Extract and save the AMI-supplied upgrade-file, Model430.exe, to the new folder.

      (3.) Ensure that the PC is connected to the network.

9. Available free at http://filezilla-project.org/

(4.) Ensure the Model 430 is connected to the network via standard Ethernet cable.

b. Direct PC-to-Model 430:

(1.) Make a new “Upgrade” folder located in an appropriate location on the PC.

(2.) Extract and save the AMI-supplied upgrade-file, Model430.exe, to the new folder. *Additional files such as an updated manual PDF (Model430Manual.pdf) and updated Magnet-DAQ app (MagnetDAQ-setup.msi) may also be included in the update.*

(3.) Connect the PC to the Model 430 using a “null-modem” Ethernet cable (also referred to as an Ethernet “crossover” cable). *Modern computer equipment may not require a crossover cable as the Ethernet ports can automatically sense the necessary configuration.*

3. Turn on the Model 430 and press ENTER at the “Turn on power supply . . .” prompt.
4. Press ***MENU*** to enter the menu system.
5. Use <◄>/<►> to navigate to *Net Settings* submenu and press ENTER.
6. Use <◄>/<►> as necessary to navigate to *Addr Assignment (Present)*.

NOTE **The Addr Assignment (Present) must show “DHCP” as originally set by AMI.**

NOTE **In the following step, the IP Address is the four part number separated by periods (.), and will change with each Ethernet connection.**

7. Use <◄>/<►> to locate IP Address (Present), similar to that shown in Figure 1.

```
0.00 A   -   IP Address (Present)
0.00 Vs      169.254.243.199 (DHCP)
```

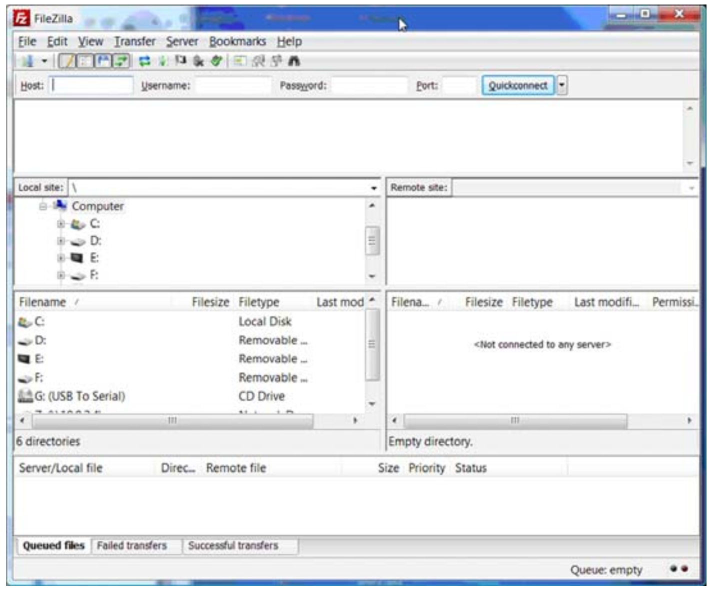
8. Make note of the IP Address (Present).

UPLOAD PROCEDURE USING FILEZILLA

An alternative upload procedure is provided on page 224 that uses the built-in command line interface for Windows FTP. It requires no software installation. If you are averse to command lines, then proceed with the following steps to use FileZilla or your other favorite FTP Client.

NOTE **The result of each of the following steps is depicted in the figure appearing above or below the action described. The actual screens will vary depending on the files and file structure on the users PC or file server, and whether FileZilla is used as the FTP Client.**

1. Open the FileZilla client application—a screen similar to the following will appear:



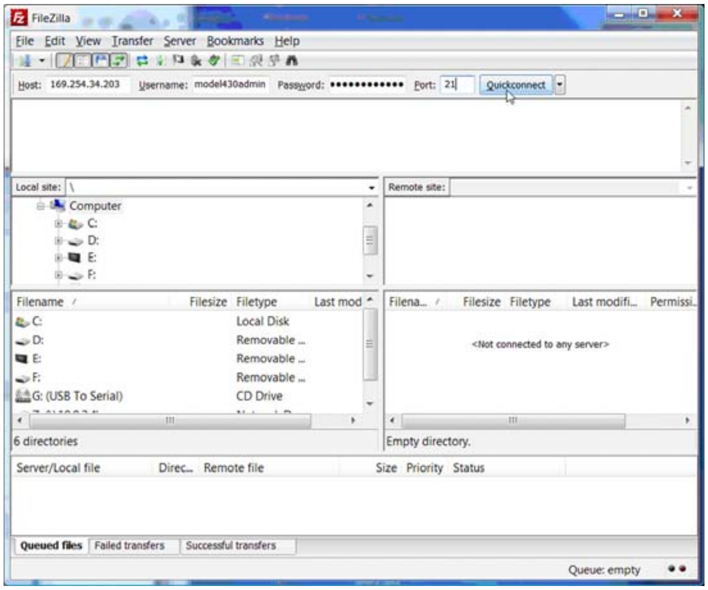
2. Enter the following information in the applicable fields:

   a. Host: the *IP Address (Present)* as noted previously

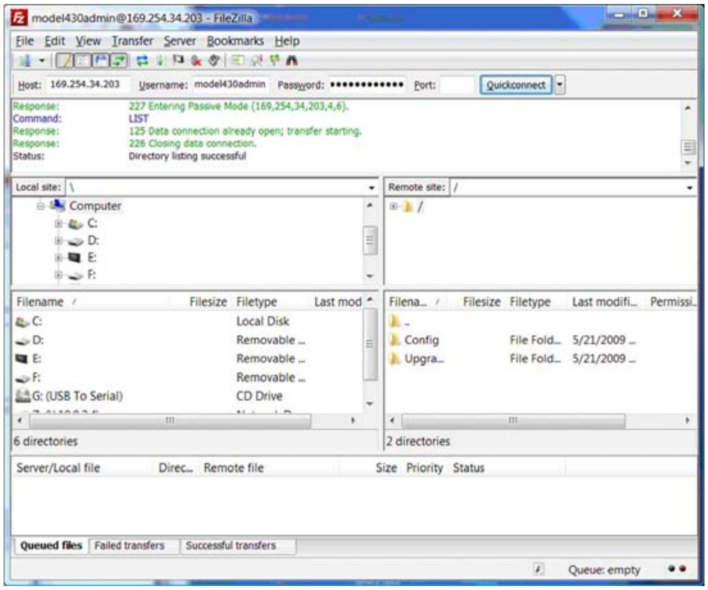
   b. User Name: *model430admin*

   c. Password: *supermagnets*

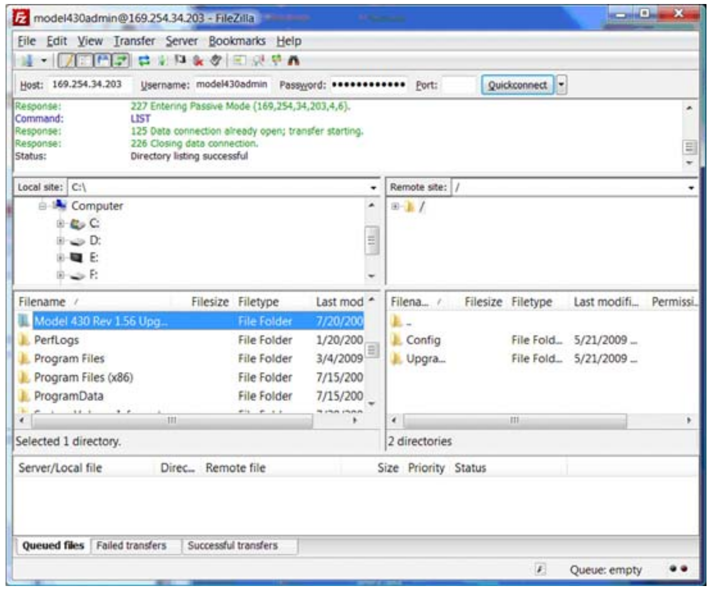
d. Port: *21*



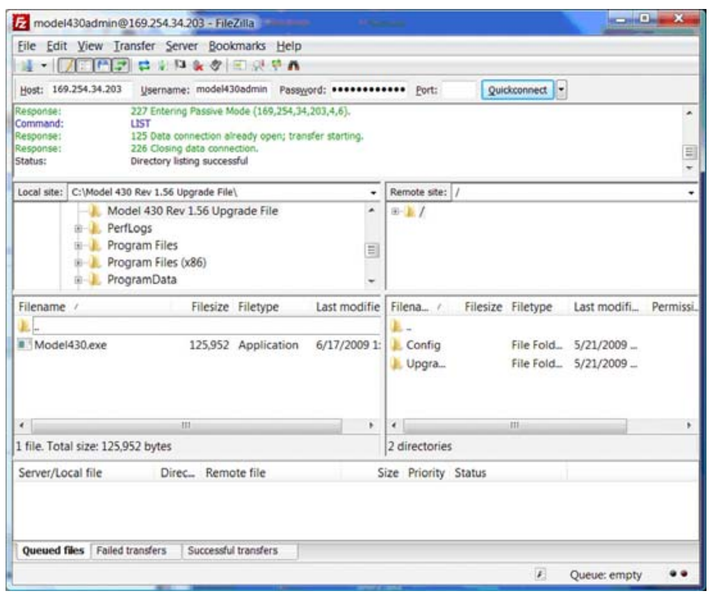
3. Click the *Quickconnect* button to connect to the Model 430 – the Remote Site section of the screen will populate.



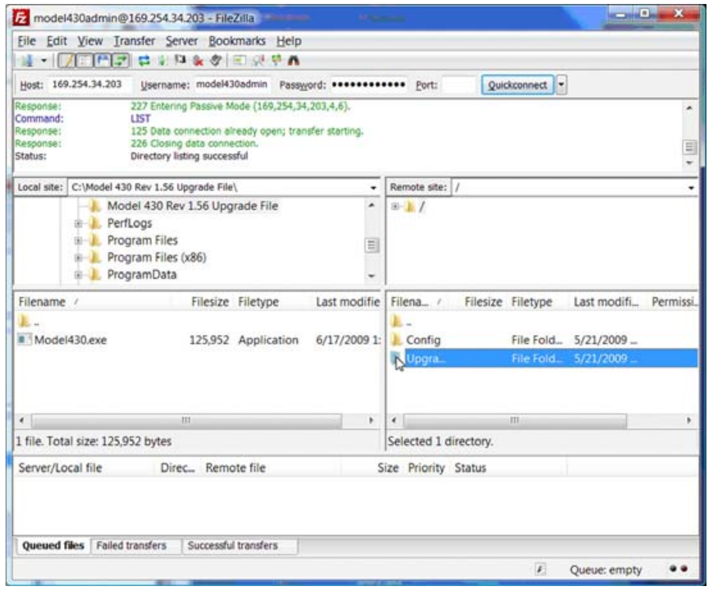
4. On the Local Site (left side representing your PC or server file system), navigate to the folder containing the *Model430.exe* upgrade file (the folder name will be that which was previously given the new “upgrade” folder.).



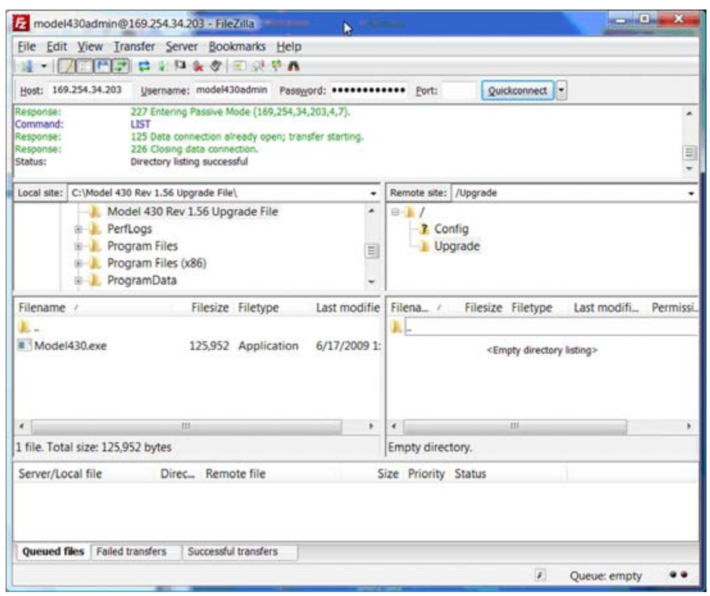
5. Double-click to open the “upgrade” folder on the Local Site (left side) of the screen – the *Model430.exe* file will appear.



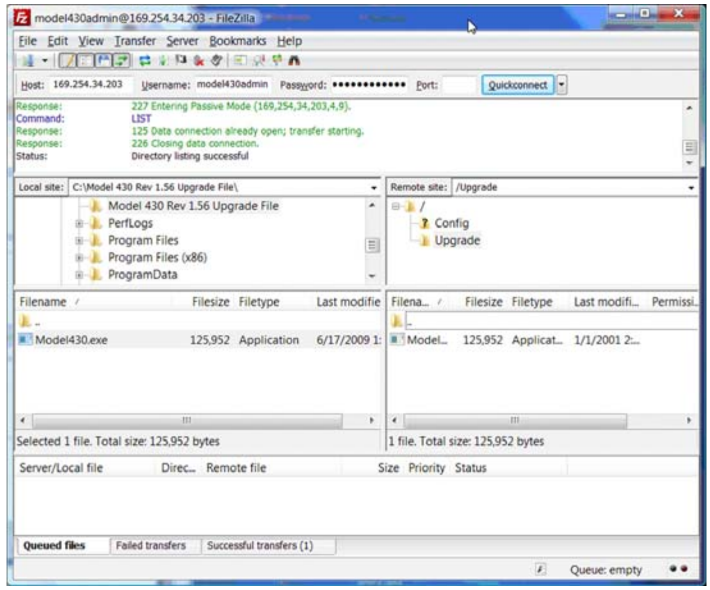
6. On the Remote Site (right side representing the Model 430 files), select the *Upgrade* folder.



7. Double-click the *Upgrade* folder to open it (the folder will be empty).



8. Select the *Model430.exe* file from the Local Site (left side) and drag it to the open Upgrade folder on the Remote Site (right side)[10].



9. If an updated manual PDF, *Model430Manual.pdf*, and updated remote control interface app, *MagnetDAQ-setup.msi*, are provided with the firmware update, then navigate to the WebServer folder on the Model 430 and replace those files with the new versions. If the WebServer folder does exist on the Model 430, please contact an AMI Technical Support Representative for further instructions.

10. Turn off the Model 430.

11. Close the FTP program.

NOTE **This completes the firmware upgrade. When the Model 430 power is turned on again after powering down, the firmware will automatically upgrade based on the Model430.exe file just placed in its Upgrade folder. View the "Loading. . . . ." screen as the Model 430 is "booting" up: the new Firmware Version will momentarily be displayed.**

12. Reboot the Model 430 Programmer by switching the power switch on the front panel off for 10 seconds and then turning the switch back on.

13. Verify that after approximately 20 seconds, the Model 430 display briefly shows the new (upgraded) firmware version[11]:

```
AMI Model 430 Programmer
 Firmware Version: 2.50
```

10. Alternatively, copy *Model430.exe* from the Local Site and paste it to the open folder on the Remote Site.

Alternative Upload Procedure using Windows FTP

Modern versions of Microsoft Windows (and other operating systems such as Linux) include a command line-based client version of FTP as a standard feature. There is no *requirement* to install a GUI FTP Client to perform the Model 430 firmware upgrade.

First, perform steps 2 through 8 as described in the *Preparation* section on page 217 (omit the FileZilla installation of step 1).

To actually perform the FTP upload to the Model 430, do the following steps:

1. Open a Windows Command Line instance and navigate to the folder where you stored the firmware upgrade during the preparation steps.
2. FTP to the instrument address on the network as identified during the preparation. The entire command line process is illustrated below:

```
C:\Model430\IoT-Firmware\Model430\X86Rel>ftp 192.168.1.12
Connected to 192.168.1.12.
220 Service ready for new user.
500 Syntax error, command unrecognized.
User (192.168.1.12:(none)): model430admin
331 User name okay, need password.
Password:
230 User logged in, proceed.
ftp> bin
200 Command okay.
ftp> cd Upgrade
250 Requested file action okay, completed.
ftp> put Model430.exe
200 Command okay.
150 File status okay; about to open data connection.
226 Closing data connection.
ftp: 213504 bytes sent in 1.66Seconds 128.93Kbytes/sec.
ftp> quit
221 Service closing control connection.

C:\Model430\IoT-Firmware\Model430\X86Rel>
```

3. Login with user name “model430admin” and password “supermagnets” (do not include the quotes).
4. Type “bin” and press Enter to ensure a binary mode transfer.
5. Type “cd Upgrade” and Enter to change to the target folder for the firmware upload.
6. Type “put Model430.exe” and Enter.
7. Type “quit” and Enter to exit.
8. Cycle power on the Model 430 and observe the firmware version banner during boot.

11. Version 2.50 is used only for purposes of this example.

UPGRADING THE MODEL 430 FIRMWARE VIA FLASH CARD READER

NOTE **These instructions are intended primarily for a Model 430 being <u>upgraded from Version 1.59 or earlier</u>. If the <u>current</u> version is v1.60 or later, upgrade should be performed via FTP according to page 217.**

NOTE **These instructions apply specifically to the Microsoft Windows operating system. For other operating systems, please make adjustments as appropriate.**

This is a one-time only procedure as future upgrades will be handled via the Ethernet communications connection on the rear panel of the instrument. An operating system file on the Compact Flash (CF) card mounted inside the Model 430 must be updated to enable the new web server functionality. The file is not accessible via FTP which means the Model 430 cover must be removed, the CF card removed, and the files updated using a CF card reader. Once this upgrade is completed, the CF card should not have to be removed in order to perform future upgrades.

HARDWARE AND SOFTWARE REQUIREMENTS

1. The zip file, *Model 430 flash card update.zip*, is required for this upgrade; the zipped files are to be extracted and copied to the CF card.
2. Host computer on a network to which the Model 430 can be connected by standard Ethernet cable

   or

   Host computer that can be connected directly to the target Model 430 via an Ethernet “null-modem” or “crossover” cable.

NOTE **Most modern computers will negotiate the direct connection cross-over automatically with a standard Ethernet cable.**

3. Standard Ethernet cable or Ethernet “null-modem” cable, as appropriate.

PREPARATION

Complete the following in preparation for the upgrade.

1. Power down and unplug the Model 430.
2. Remove the cover from the Model 430 as follows:

   a. Remove the screws securing the cover on the back edges of the instrument (two near each side of the instrument).

b. Remove the screws securing the cover just behind the front panel (two on each side of the instrument).

3. Remove the CF card[12] from the Model 430 as follows:

   a. Grasp the edges of the card with the thumb and forefinger.

   b. Gently pull outward to remove the card.

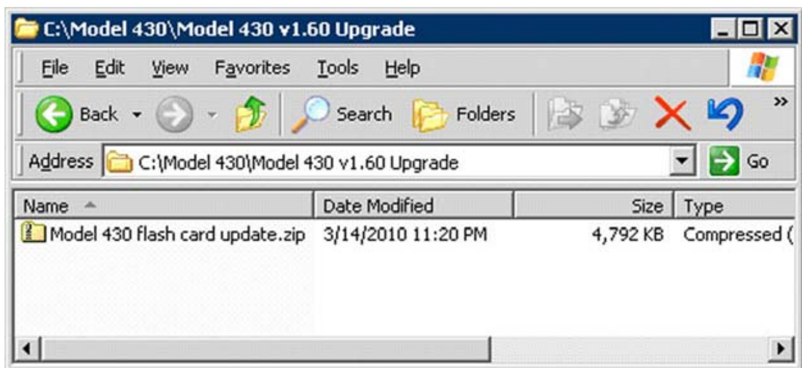
4. Insert the CF card into a CF reader attached to (or internal to) a host computer.

5. Browse to *My Computer* on the host computer to verify the CF card is visible as a drive.

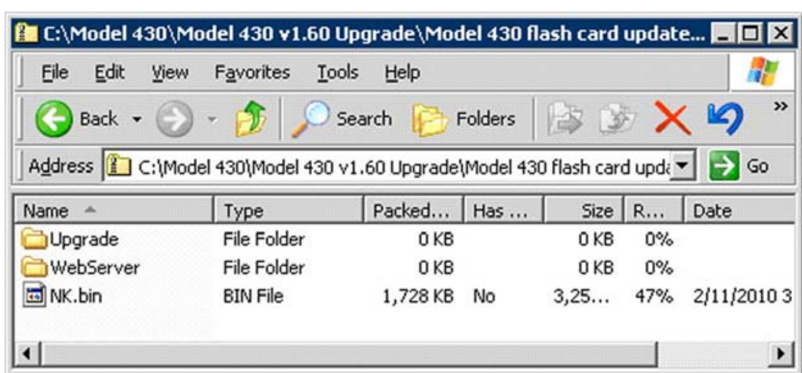
UPGRADE PROCEDURE

The following steps provide detailed instructions to complete the upgrade.

1. Copy the zip file *Model 430 flash card update.zip* to a location on the host computer – for example, *C:\Model 430\Model 430 v1.60 Upgrade*:



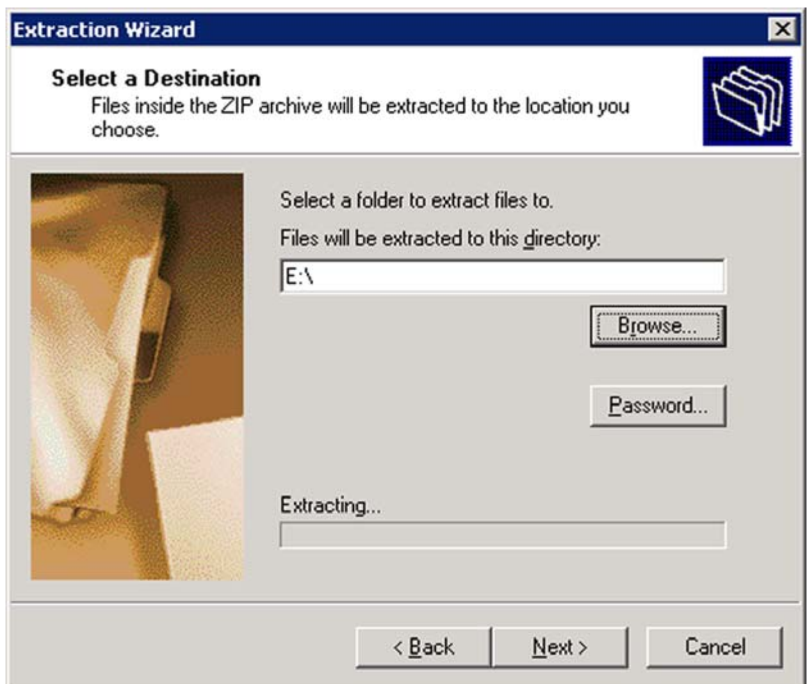
2. Double-click the zip file to open it – the following or similar screen should appear with the files shown:



12. The Compact Flash card is located at the front right corner of the Model 430 motherboard.

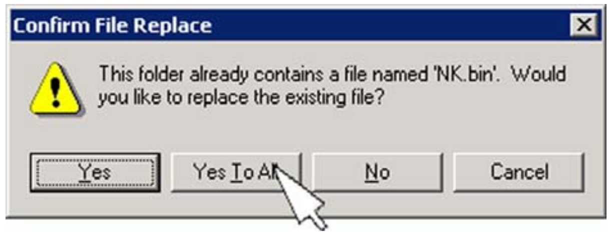
3. Choose *File* > *Extract All…* to start the extraction wizard:

4. Click ***Next*** until prompted with *Select a Destination*:



5. Browse to *My Computer* and choose the top level (root) of the drive associated with the CF card (for example **E:** or **G:**) and select ***Next***.

6. When prompted with the *Confirm File Replace* dialog, select ***Yes To All***.



7. When the extraction process concludes, select ***Finish***.
8. Close all open windows for the CF drive.
9. Use the ***Safely Remove Hardware*** icon in the tool tray to eject (unmount) the CF card from the host computer.
10. Remove the CF card from the card reader.
11. Re-install the CF card in the Model 430 - ensure the card is seated properly.
12. Re-install the cover on the Model 430 using the previously removed screws.

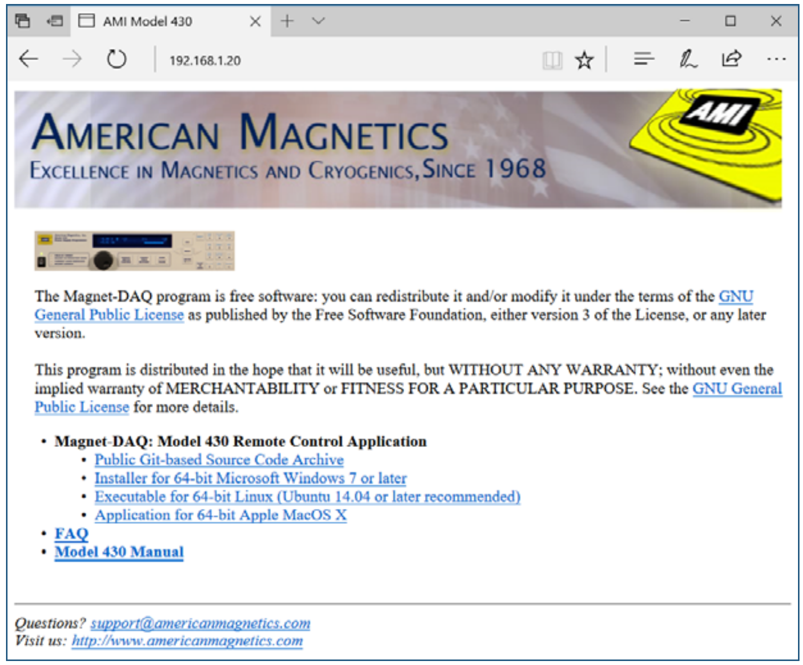
NOTE **The Model 430 and the host computer must share the same network address scheme and be attached to the same physical network in the following process.**

13. Verify that the web interface is functioning correctly as follows:
    a. Connect the Model 430 to the host computer using one of the following two methods:
        (1.) Via Ethernet cable to the same physical network *as the host computer*.
        (2.) Via "crossover" or "null modem" Ethernet cable directly to the host computer's Ethernet port.
    b. Plug in and power up the Model 430.
    c. As the Model 430 boots up, watch the front display and verify that it shows *Firmware Version: 1.62*[13] (or other version being upgraded to).
    d. Press <***ENTER***> at the *Turn on power supply* prompt.
    e. Using the Model 430 menu system, *Menu > Net Settings > IP Address (Present)*, determine the *IP Address* of the Model 430.

13. Display time may vary depending on network speed - refer to section on page 189.

f. Open a web browser on the host computer and type the IP address[14] of the Model 430 into the address bar.

g. The following screen should appear:



14. This completes the installation and verification of the Model 430 Firmware Upgrade.

14. In the form http://xxx.xxx.xxx.xxx, where the "xxx" values match the *IP Address (Present)* of the Model 430.

MAGNET-DAQ: MODEL 430 REMOTE CONTROL[15]

The Model 430 can be accessed via a network connection[16] with fully functional control.[17] This is accomplished through the Ethernet connection on the rear panel using TCP/IP protocol via a host computer. The connection and control can be established through a locally connected computer or remotely through a network or even the Internet; the actual control is accomplished through the SCPI remote commands as documented in the “Remote Interface Reference” section beginning on page 127.

The open-sourced[18] Magnet-DAQ application is provided to manage the remote control with a familiar graphical interface. The source code and latest binary (i.e. pre-compiled) downloads for the application are available at:

https://bitbucket.org/americanmagneticsinc/magnet-daq

To utilize the Magnet-DAQ application, the Model 430 Programmer RJ-45 Ethernet port must be connected either directly to a host computer or through a computer network on which the host computer resides or can directly access:

1. For a host computer on a network, connect a standard Ethernet cable between the Model 430 and the network.
2. For a direct hardwired connection between the Model 430 and a host computer, use a “null-modem” or “crossover” Ethernet cable connected from the Model 430 to the host computer.

NOTE **Most modern computers will negotiate the direct connection cross-over automatically with a standard Ethernet cable.**

3. Once connected, plug in and power up the Model 430.
4. Press <***ENTER***> after responding to the “Turn on power supply . . .” prompt.

NOTE **Allow up to 90-seconds (from power-up) for the TCP/IP link between the Model 430 and host computer to be established.**

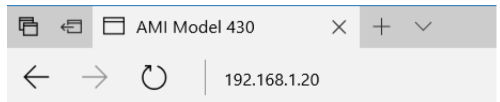
In order to access the Model 430 using the Magnet-DAQ application, the Model 430 *IP Address* must be known. The *IP Address* can be determined after Model 430 power-up. The following example illustrates how the *IP Address* may be determined using the Model 430 menu system:

15. Requires Model 430 version 2.50 or later firmware.
16. Third-party remote software, such as National Instruments LabVIEW, can also be used.
17. With the exception of the Power ON/OFF switch.
18. Subject to the GPL version 3.0 license.

5. *IP Address*: *Menu > Net Settings > IP Address (Present)*.

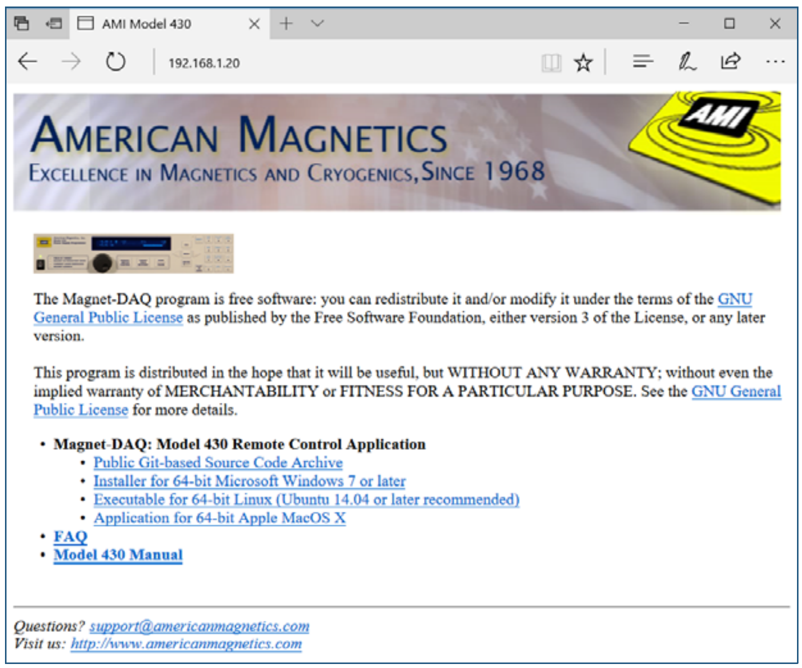
```
0.00 A   -   IP Address (Present)
0.00 Vs      192.168.1.20 (DHCP)
```

Open a web browser on the host computer. In the address field, type the *IP Address*, and press <***ENTER***>. For example:



IP Address Entry in Browser Address Field

The following initial (home) screen should appear:



Initial Screen for Browser Access of the Model 430

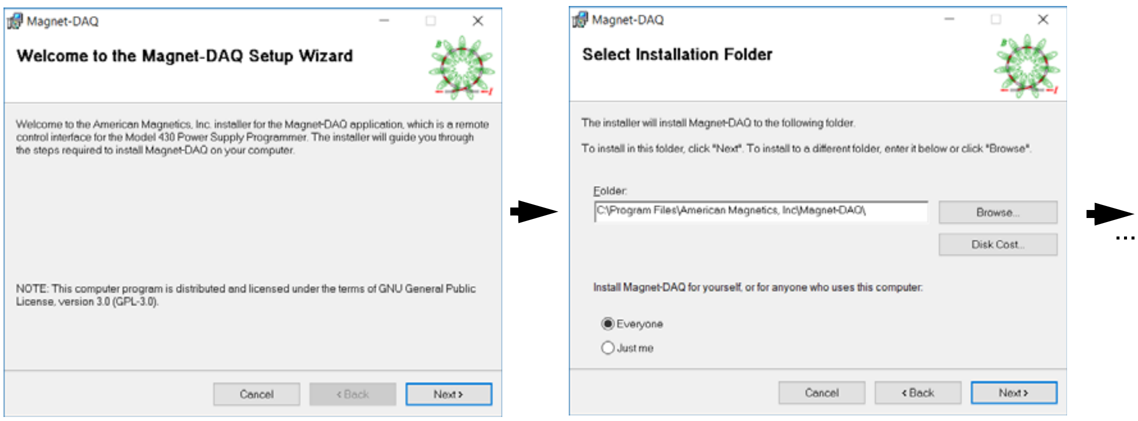
The *Magnet-DAQ: Model 430 Remote Control Application* section is the primary feature of this HTML page. Download links for the pre-compiled installers or executables are provided for various computer platforms.

NOTE **Please note that the version provided was current at the time the Model 430 was shipped. Check the AMI website, or the on-line Git-based Source Code Archive, for updated versions of the Magnet-DAQ application. Updated versions of the Magnet-DAQ may also require updating the Model 430 firmware.**

The initial screen also includes links to the *Model 430 Manual* in Adobe PDF form along with the *FAQ* (*Frequently Asked Questions)* related to the Magnet-DAQ application (all stored in the Model 430 firmware). There are also links to the AMI website and an e-mail form for contacting AMI Customer Support.

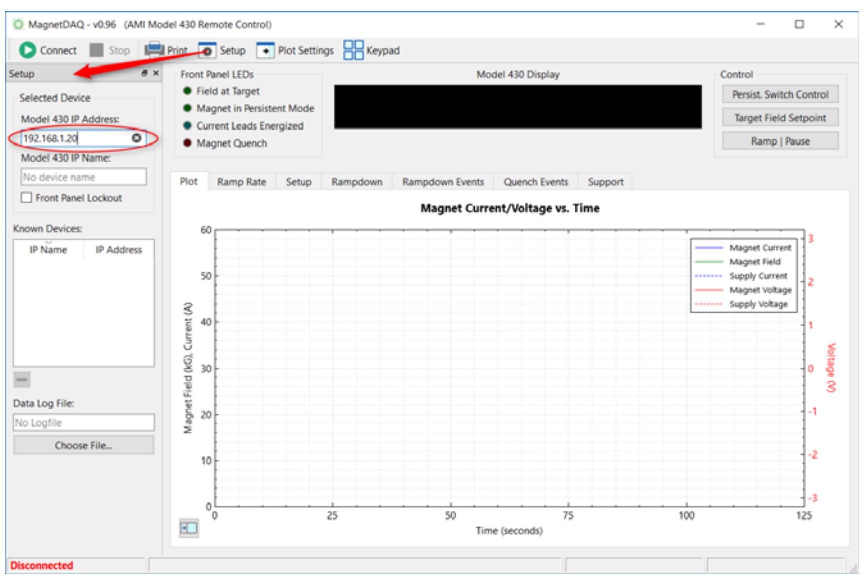
6. Choose the desired Magnet-DAQ version for the appropriate operating system and follow the installation instructions for each.

   The Windows version installation will be illustrated herein which is provided in the form of an installer. After the installer download is complete, simply launch the installer and follow the familiar installation wizard (using the Next button) to complete the process:



Windows-version Installation Wizard for the Magnet-DAQ Application

7. Launch the Magnet-DAQ application, choose the Setup panel, and enter the IP address discovered in Step 5 above:



8. Press the Connect toolbar button to start communication.

9. Use the provided Magnet-DAQ interface to remotely control the Model 430. The Keypad panel provides a remote keypad function. For more details, refer to the integrated Help provided in the Magnet-DAQ application.

SHORT-SAMPLE MODE[19]

The Model 430 also features the ability to operate as a short-sample controller. *Short-sample* refers to samples of superconducting wires of relatively short length as compared to lengths required for a wound magnet, typically tested in the presence of various background magnetic field levels. The short-sample test is designed to determine critical current density limits for various field levels for the wire sample.

In the Short-Sample Mode, the Model 430 commands a connected power supply in voltage-controls-current mode, i.e. the Program Out connector (see page 196) outputs a voltage that corresponds to the current output limit of a connected power supply. *The connected power supply must support remote current limit programming by external analog voltage.*

CAUTION **The Short-Sample Mode includes a sample quench detection feature. It is recommended that the sample quench detection always be ON and that voltage taps across the sample be connected to Auxiliary Input 2. It is possible to destroy a sample (via overheating) if the Model 430 is allowed to continue ramping or hold a current for a sample that has quenched. Samples should not be left unattended when actively ramping the sample current.**

If the sample has quenched, the Model 430 will indicate the sample current at which the quench was detected and immediately command and hold the supply output current at 0 A until the sample quench detection state is cleared.

The typical system setup for short-sample testing will require a data acquisition computer to query and record the sample voltage vs. sample current and an application to plot the real-time result.

In Short-Sample Mode several features of the Model 430 applicable only to operation with a magnet are disabled. The changes include:

- All menu items associated with the Persistent Switch operation are removed.
- The Voltage Limit function is removed.
- The units display for current is always amperes since *there is no magnet connected to the 430* with an associated coil constant (only the short-sample).
- The sample voltage is measured via Auxiliary Input 2 (see page 200) and is reported in the default display as `Vss` in microvolts. An external gain factor of

19. Contact an AMI Technical Support Representative for details on how the Short-Sample Mode can be enabled and the latest data acquisition options for microvolt sampling.

10,000 is *required* for the sample voltage signal connected to Auxiliary Input 2 in Short-Sample Mode.[20]

```
+50.00 A   -   Status: Holding
+24.53 Vss     Short-Sample Mode
```

NOTE **The sample voltage must be connected to the Auxiliary Input 2 for the sample quench detection feature to function. Sample quench detection is defined as a sample current magnitude greater than 90 microvolts. The quench threshold of 90 microvolts is a fixed internal parameter.**

- The custom Supply parameter "V-V Mode Input Range" is changed to "V-I Mode Input Range" to reflect voltage-commands-current operation of a connected power supply.
- The Load submenu of the Setup menu is limited to four parameters: Stability Setting, Current Limit, Sample Voltage Null, and Sample Quench Detect.

  A Stability Setting of 0% is recommended for Short-Sample Mode unless otherwise directed by an AMI Technical Support Representative.

  The Current Limit in this context refers to the maximum allowable current through the short-sample under test.

  The Sample Voltage Null feature when exercised will quickly average several sample voltage (Vss) measurements and determine an offset to apply to the sample voltage to report 0 Volts for the `Vss` display and remote query. *This offset is not saved between power cycles* of the Model 430 and may be exercised as many times as desired to null out sample voltage offsets.

```
+50.00 A   -   Sample Voltage (Vss) Null
+24.53 Vss    ▶Press ENTER to Zero Vss
```

- The following remote commands and queries generate the error:

  `-109,"N/A in present mode"`

  when the Model 430 is operating in Short-Sample Mode:

  `CONFigure:VOLTage:LIMit`
  `CONFigure:COILconst`
  `CONFigure:RAMPDown` (all subcommands)
  `CONFigure:RAMP:RATE:FIELD`
  `CONFigure:FIELD:UNITS`
  `CONFigure:PSwitch` (all subcommands)

20. AMI offers an external low-noise amplifier to scale microvolt sample voltages to a range that can be read by AUX Input 2.

```
CONFigure:LOCK:PSwitch:CONTRol
CONFigure:LOCK:PSwitch:SETtings
CONFigure:LOCK:VOLTage:LIMit
CONFigure:LOCK:VOLTage:VS-VM
CONFigure:LOCK:QUench:RATE
CONFigure:LOCK:FIELD-CURRent
CONFigure:LOCK:FIELD:UNITS
CONFigure:LOCK:COILconst
CONFigure:LOCK:ABsorber
CONFigure:LOCK:RAMPDown
CONFigure:QUench:RATE
CONFigure:ABsorber
INDuctance?
VOLTage:SUPPly?
VOLTage:LIMit?
VOLTage:MAGnet?
CURRent:MAGnet?
COILconst?
PSwitch?  (all subcommands)
PERSistent?
LOCK:PSwitch:CONTRol?
LOCK:PSwitch:SETtings?
LOCK:CURRent:RATING?
LOCK:VOLTage:LIMit?
LOCK:VOLTage:VS-VM?
LOCK:QUench:RATE?
LOCK:FIELD-CURRent?
LOCK:FIELD:UNITS?
LOCK:COILconst?
LOCK:ABsorber?
LOCK:RAMPDown?
QUench:RATE?
ABsorber?
RAMP:RATE:FIELD?
FIELD:MAGnet?
FIELD:TARGet?
FIELD:UNITS?
FIELD:PRESent?
```

- The following remote queries are available only in Short-Sample Mode:

  `CURRent:SAMple?`
  Returns the sample current in amperes.

  `VOLTage:SAMple?`
  Returns the sample voltage in microvolts.

A

B

C

D

E

F

I

T

U

V

Z