INSTALLATION, OPERATION AND MAINTENANCE

INSTRUCTIONS FOR THE AMI

MODEL 410, 411, AND 412

MAGNET POWER SUPPLY PROGRAMMERS

I. INTRODUCTION

The AMI Model 410, 411 and 412 Magnet Power Supply Programmers are a family of electronic power supply programmers used to control both linear and switching power supplies for superconducting magnet systems. The basic functions of these three models are identical. The Model 410 is the basic power supply programmer, the Model 411 provides an indication of magnet voltage with the programmer and the Model 412 provides the same features as the Model 411 as well as providing a regulated current source for magnet persistent switch heater operation. The front and rear panels are shown in figures 1 and 2.

The Model 410 is available as either a stand alone cabinet model or in a EIA standard 3 1/2 inch rack version. The Model 411 and 412 are only available in EIA rack mount versions (3 1/2" x 19"). This manual covers the installation, operation and maintenance of the Model 410, 411 and 412. The readers should ignore the sections of the manual (if any) that do not apply to their particular instrument as the manual is written to cover all three models.

An important consideration in working with superconducting magnets is to charge the magnet current linearly in time or in some non-linear way as a function of time. Attempting to inject the desired function into the current control terminals of an ordinary power supply usually results in a current oscillation in the magnet due to the interaction of the large inductance zero resistance magnet with the power supply. Alternatively, since the voltage across a superconducting coil is $V=L*dI/dt$, one can also control the magnet current by appropriately controlling the voltage across the coil. However, the voltage across the coil is not the same as the voltage produced by the power supply because of the voltage drop in the current leads. Large errors result if the desired function is simply introduced at the voltage control terminals of the power supply. The Model 410 family of programmers eliminate these problems by measuring the magnet current (an external shunt is required), comparing the current to the desired current functions and then producing the appropriate voltage across the magnet which is necessary to achieve the desired result. Compensation for the voltage drop in the current leads is achieved automatically with no adjustments required on the part of the operator. The programmer provides for remote operation via computer utilizing a proper interface between the computer and the programmer's 25 pin D connector mounted on the rear panel. Analog voltages corresponding to ramp rate and current limit are used as inputs and magnet current is supplied as an output at this connector.

A magnet quench protection circuit is incorporated to rapidly reduce the power supply output voltage to zero in the event a magnet quench is detected. The function is defeatable from the front panel.

II. SPECIFICATIONS

Input power	115 or 230 Vac, 50-60 Hz
Ramp output	0 to 5 VDC
Charging rate	0 to 10 Amps/sec
Charging rate ranges	0.1, 1 and 10 Amps/sec
Charging rate adjustment	10 turn potentiometer
Current limit	10 turn potentiometer
Current control	Up/Pause/Down switch
Voltage limit	10 turn potentiometer

III. INSTALLATION

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

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

This document contains operating instructions as well as calibration instructions. The calibration procedure is to be performed only by trained service personnel familiar with electrical safety precautions and proper energized electrical safety procedures. Do not perform any operations on any AMI equipment with the cover removed unless qualified to do so and another person qualified in first aid and CPR is present.

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

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

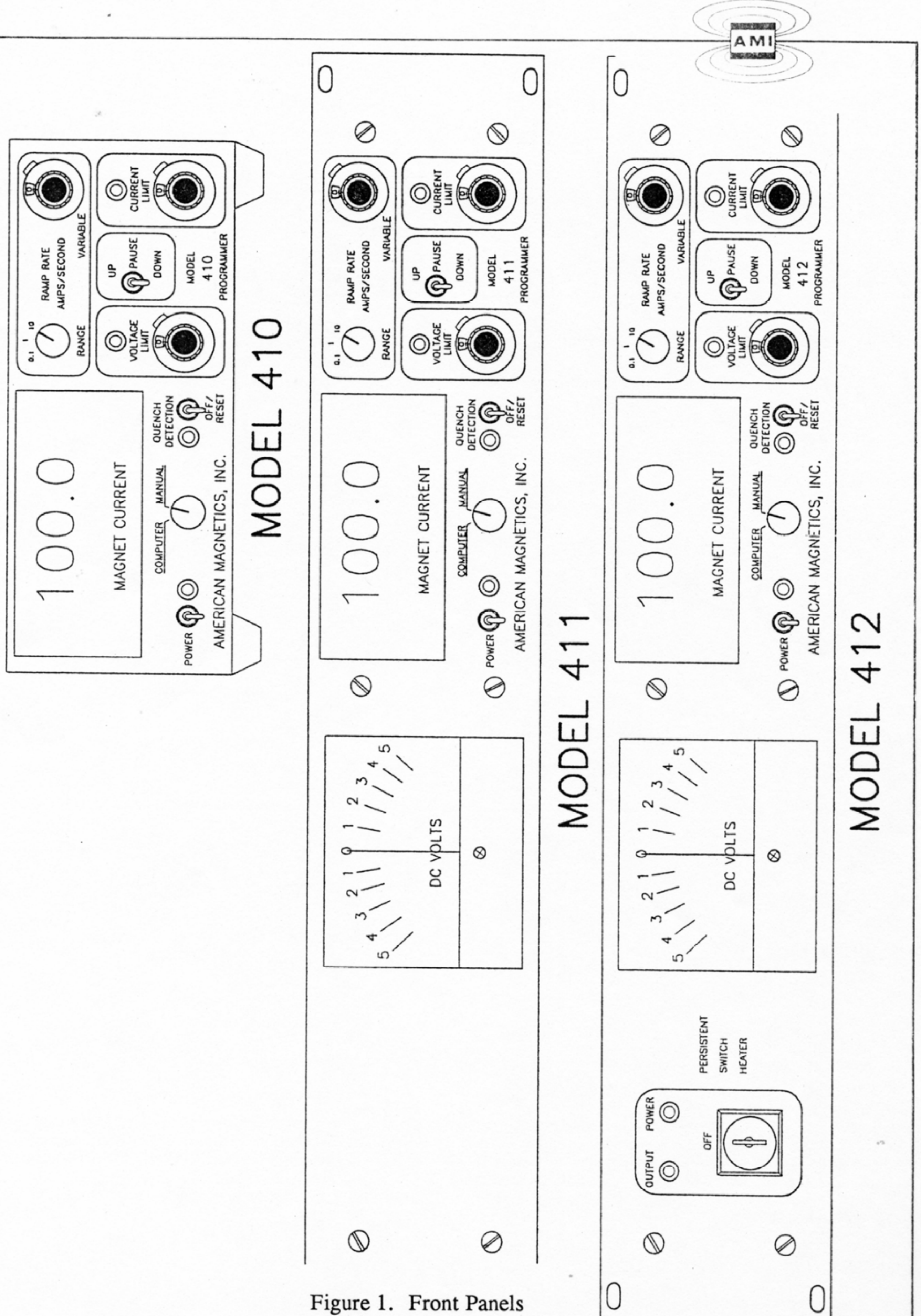


Figure 1. Front Panels

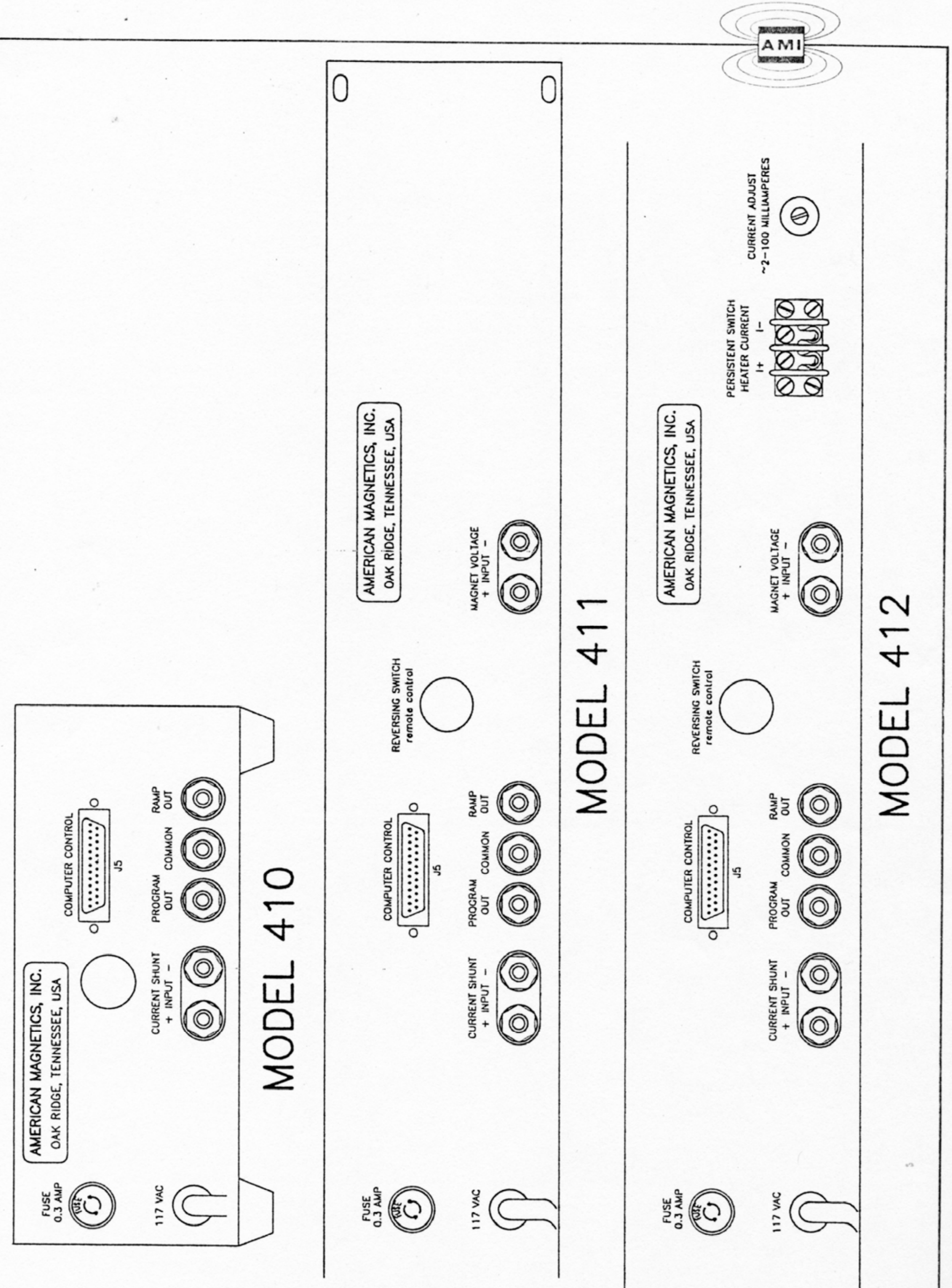


Figure 2. Rear Panels

1. Carefully remove the programmer from the shipping carton and remove all packaging materials. Inspect the equipment for any physical damage that may have occurred during shipment.

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

2. Install the Model 410 programmer on a flat secure surface or install the Model 411, 412 programmer in a 19 inch rack by securing the front panel to the cabinet rails with mounting hardware supplied by the cabinet manufacturer. It is recommended to support the rear of the instrument in some fashion.

3. If the programmer and power supply were purchased as part of a console, they should already be wired together prior to shipment. In any event, the wiring should be checked prior to applying power to the equipment.

4. Figure 3 depicts a typical system configuration consisting of a superconducting coil, energy absorber (optional), power supply and programmer.

5. A suitable power supply for operating your system should be available.

    <u>NOTE:</u> The power supply is part of the feedback loop for the programmer and therefore the noise and stability of the system is a function of the quality of the power supply. The ideal power supply has zero phase shift, a voltage control mode where 1 volt input produces 1 volt output, has zero current ripple and would be much slower than the programmer time constant (0.1 millisecond, typically). Some switching power supplies may be too noisy for this application. AMI recommends the Hewlett-Packard Model 6259B or Model 6260B, as modified by AMI for use with superconducting magnets, where an extremely quiet and stable linear power supply is required. AMI also recommends the Power Ten Model 10100, as modified by AMI, in applications where more power supply noise can be tolerated. The modifications performed on these power supplies includes an output rectifier to protect the power supply from damage due to transfer of the stored energy in the superconducting magnet back to the supply.

    *<u>NOTE:</u> An energy absorber should be installed in a system where it is important to ramp the magnet down at the maximum rate (i.e. the shortest time). The magnet discharge rate is determined by the voltage across the magnet according to the equation V=L*dI/dt and without an energy absorber, the discharge voltage is determined by the IR drop in the system power supply cables and many be as low as 0.1 volt. Since the inductance is*

typically several Henries, it can take a very long time to discharge a magnet without an energy absorber. For energy absorber installation, refer to its reference manual.

6. Ensure the power supply and programmer are unplugged and power switches are in the OFF position.

> ►***WARNING:*** *Superconducting magnets can produce and extremely large inductive voltages that can be dangerous and potentially fatal. Ensure that all magnets are completely discharged and all power supplies deenergized before making or breaking any electrical connection.*

7. Connect the magnet power leads from the energy absorber (or directly from the power supply if the system does not contain an energy absorber) to the magnet's vapor cooled current lead connection points.

8. Locate the current shunt leads terminated in banana plugs from the energy absorber (or power supply if the system does not have an energy absorber) and connect to the jacks marked CURRENT SHUNT INPUT on the rear panel of the programmer. Ensure proper polarity by plugging red-to-red and black-to-blue.

9. Locate the leads marked PROGRAM OUT and COMMON from the power supply. Connect these into the appropriately marked plugs on the rear panel of the programmer.

> *NOTE:* *If using a Hewlett Packard power supply with the programmer, ensure the COMMON lead contains a 750Ω resistor in series with the lead. Refer to the power supply manual.*

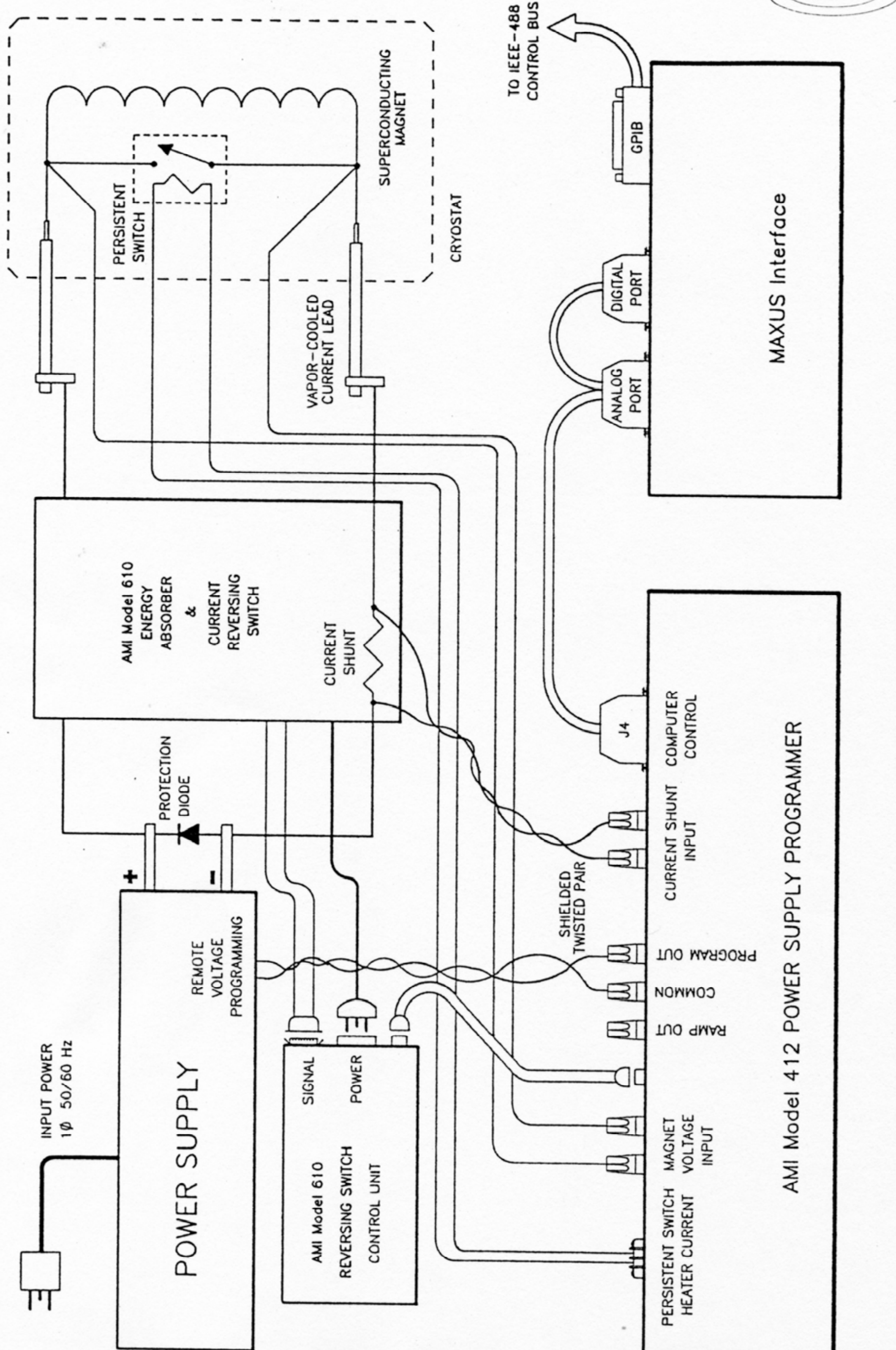
10. Locate the magnet voltage tap leads (blue and yellow) and connect to the terminal strip in the programmer rear panel marked MAGNET VOLTAGE INPUT. Connect blue to positive and yellow to negative (Model 411 and 412 only).

11. Locate the wires on the magnet from the persistent switch heater and connect them to the terminals marked PERSISTENT SWITCH HEATER CURRENT on the rear panel of the programmer (red to positive and black to negative) [Model 412 only].

12. Connect an appropriate computer interface to the rear panel computer control connector J5. Two analog inputs and one analog output minimum is required for computer operation (optional). A pin out of the 25 pin D-connector appears in Figure 6.

13. Connect the programmer and power supply to appropriate AC power sources.

Ensure the programmer line cord and the power supply are plugged into the appropriate voltage source. The



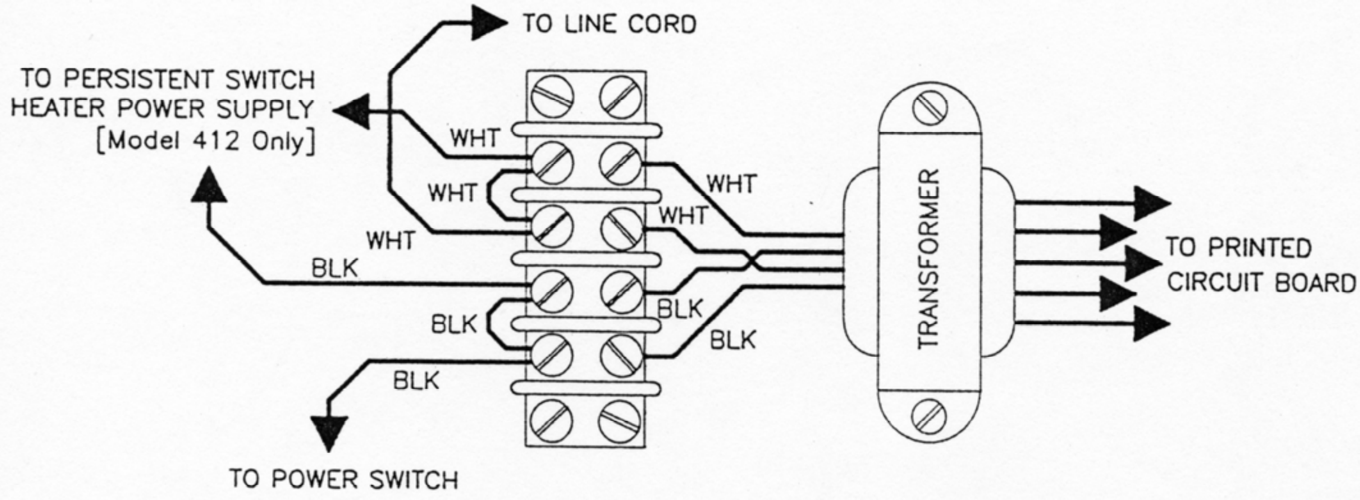
TYPICAL SUPERCONDUCTING MAGNET SYSTEM INTERCONNECTIONS

Figure 3.

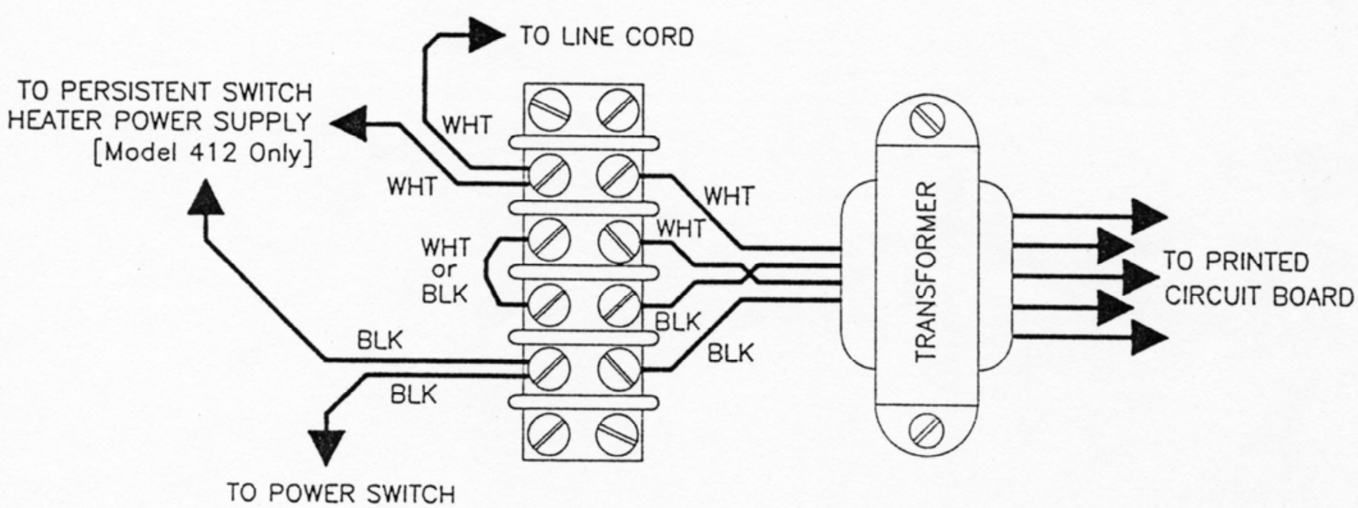
REFER TO POWER SUPPLY OPERATIONS MANUAL

FOR PROPER POWER SUPPLY STRAPPING FOR

REMOTE PROGRAMMING BY EXTERNAL VOLTAGE, VOLTAGE MODE.

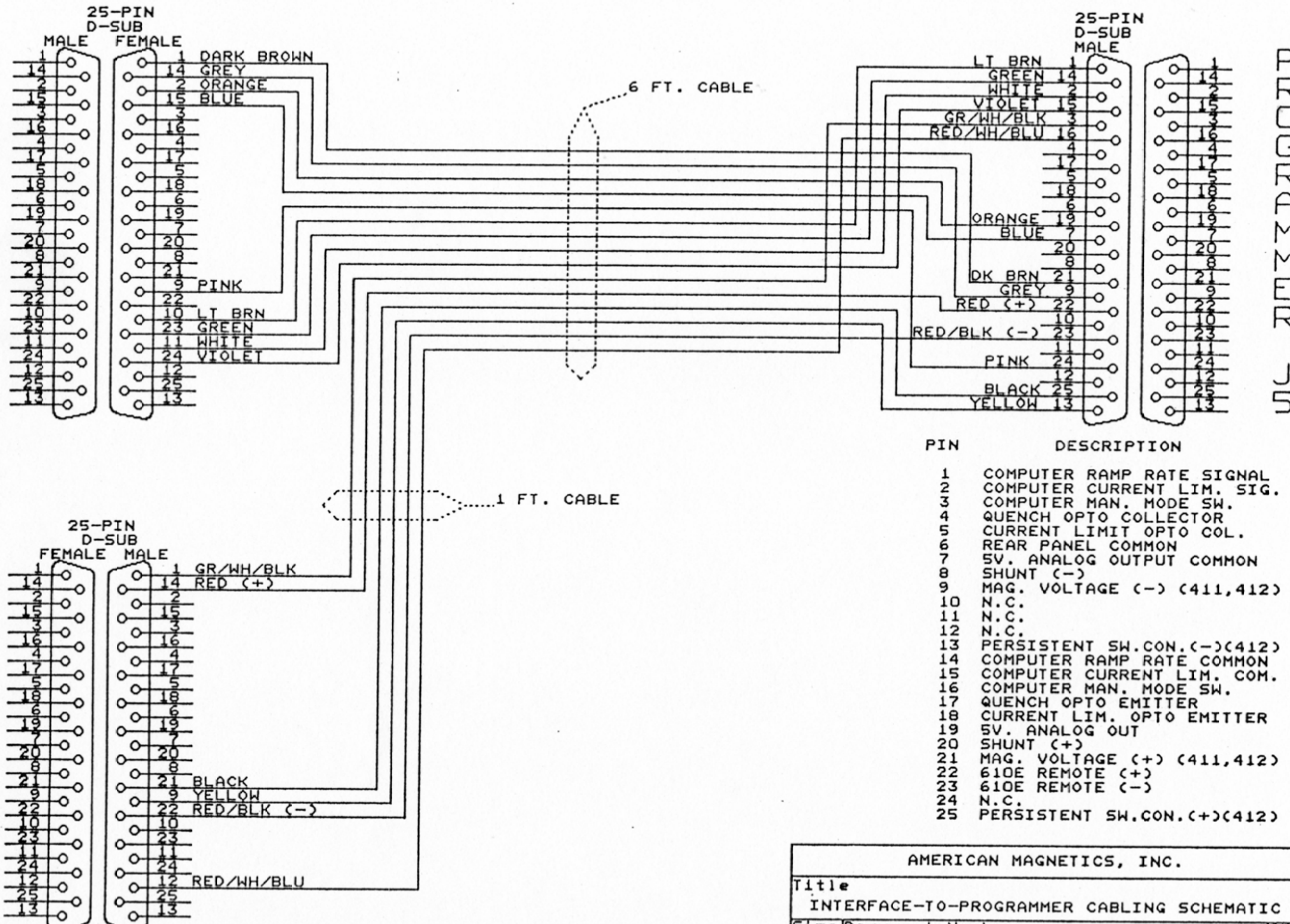


WIRING CONFIGURATION FOR 115VAC OPERATION



WIRING CONFIGURATION FOR 230VAC OPERATION

Figure 5.



PIN	DESCRIPTION
1	COMPUTER RAMP RATE SIGNAL
2	COMPUTER CURRENT LIM. SIG.
3	COMPUTER MAN. MODE SW.
4	QUENCH OPTO COLLECTOR
5	CURRENT LIMIT OPTO COL.
6	REAR PANEL COMMON
7	5V. ANALOG OUTPUT COMMON
8	SHUNT (−)
9	MAG. VOLTAGE (−) (411,412)
10	N.C.
11	N.C.
12	N.C.
13	PERSISTENT SW.CON.(−)(412)
14	COMPUTER RAMP RATE COMMON
15	COMPUTER CURRENT LIM. COM.
16	COMPUTER MAN. MODE SW.
17	QUENCH OPTO EMITTER
18	CURRENT LIM. OPTO EMITTER
19	5V. ANALOG OUT
20	SHUNT (+)
21	MAG. VOLTAGE (+) (411,412)
22	610E REMOTE (+)
23	610E REMOTE (−)
24	N.C.
25	PERSISTENT SW.CON.(+)(412)

AMERICAN MAGNETICS, INC.			
Title: INTERFACE-TO-PROGRAMMER CABLING SCHEMATIC			
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Figure 6.

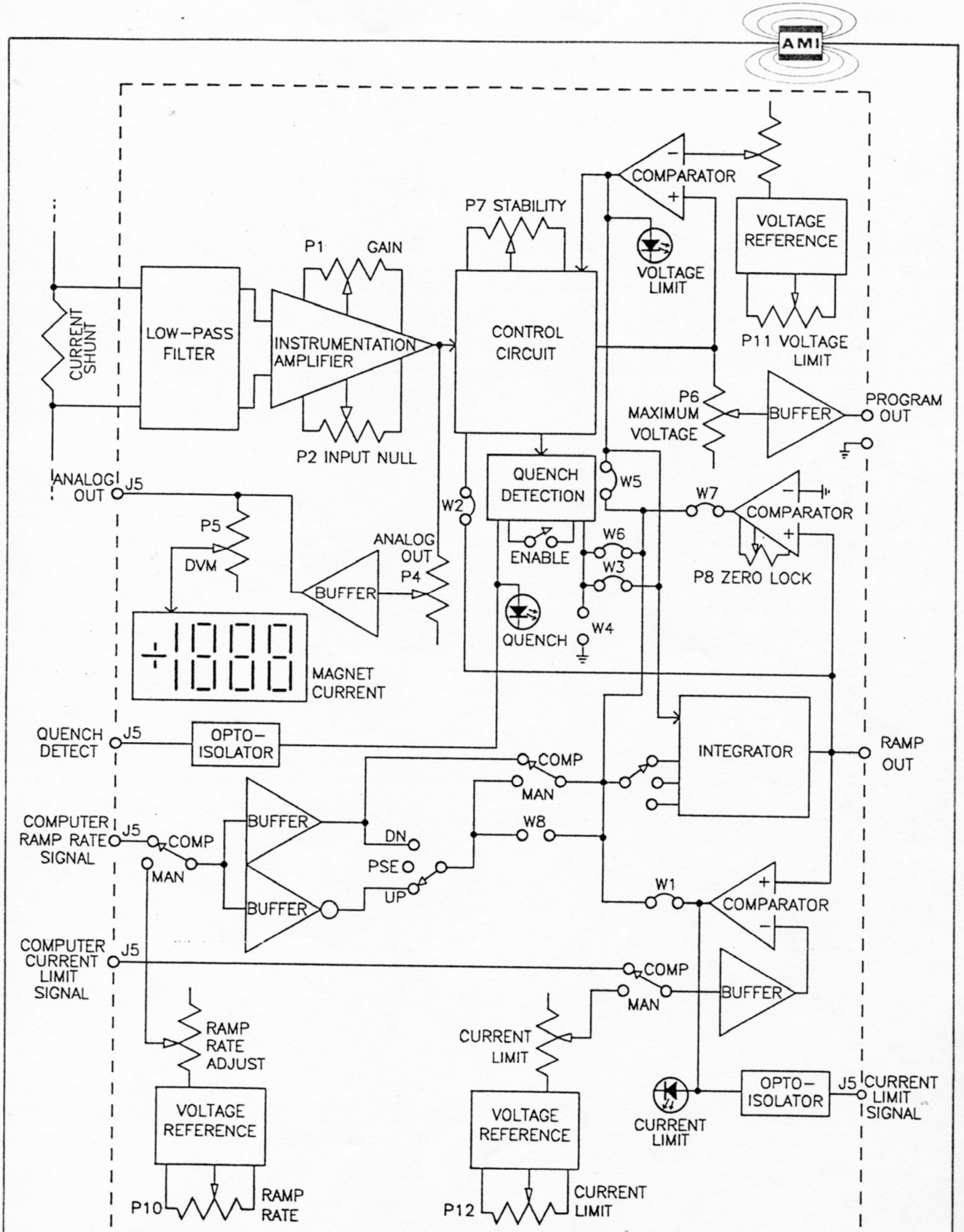

Figure 7. Block Diagram.

programmer may be operated on 110V ac or 220V ac, 50 or 60 Hz. Instruction for proper wiring (or to change) the input voltage transformer are include in figure 5. The voltage the unit was wired for from the factory is marked on the rear panel.

IV. DESCRIPTION OF OPERATION

The programmer can be operated in *three modes*:

Mode A is used to control a magnet by manually ramping the current up and down in a linear fashion. This will be referred to as the normal mode of operation.

> *NOTE:* *Do not connect any electronic device or wiring to the Ramp Out connector (green) on the rear of the instrument in Mode A or Mode B operation. This connection can only be used for Mode C operation.*

Mode B is used to control the magnet via computer. Analog ramp rate and current limit signals are supplied to the computer control connector and an analog representation of magnet current is read back from the programmer to the computer. Operation in this mode requires either a DAC/ADC interface card, a GPIB card and controller or RS-232 card and controller.

Mode C allows use of the programmers internal ramp generator for other laboratory uses.

The following paragraphs provide a description of the front panel displays and controls.

1. Power Switch - This switch energizes and de-energizes the programmer. In the POWER position the programmer is energized and the green POWER LED should be lit.

2. Charge Rate - The RAMP RATE, AMPS/SECOND will select a 0.1, 1 or 10 amperes/second charge rate. The VARIABLE ramp rate is a ten turn potentiometer that divides the selected range into sub-increments (i.e. 1 amp/sec is controlled from 0.1 to 1 amp/sec).

3. Up/Down/Pause switch - The magnet current can be controlled for ramp up, ramp down, or pause, depending on the setting of this switch. If the switch is left in the Up position, the current will ramp up to the Current Limit setting. Allowing the magnet current to be controlled by the current limit setting produces a constant, highly stable, magnet current. When the switch is in the pause position, the magnet current can drift slightly depending on the stability of the ramp generator.

4. The Current Limit is a ten turn potentiometer that will set the upper limit the programmer will ramp to (i.e. when using a 100 amp power supply a setting of 9 will limit the magnet current to approximately 90 amperes). When the current reaches the current limit the CURRENT LIMIT LED will light. The current limit can be reset at any time. If the Up/Down/Pause switch is in the UP position the Current Limit will control the current as follows: If the current limit is moved to a higher value from the locked mode, then the ramp will restart at the rate set by the RATE dial and RATE RANGE switch until the

current limit is reached again. If the current limit is reduced to a lower value, then the current will ramp down to the lower value at the set rate and lock in at the new current limit.

5. The Voltage Limit controls the output voltage maximum value. The maximum value is normally set at 10 volts when the programmer is attached to a 10 volt in/10 volt out power supply. THIS DIAL SHOULD BE SET TO 10. In some special cases, e.g. short sample measurements, it might be desirable to limit the voltage. However, any time the voltage limit light is on the ramp rate will be non-linear and the current will not reach the current limit linearly. When the voltage limit is reached the red VOLTAGE LIMIT LED will light.

6. Digital Current Meter - This meter reads the power supply current as read from the current shunt.

7. The Magnet Voltage indicates the voltage across the magnet. (Model 411 and 412 Only)

> *NOTE: It is convenient to have the magnet voltage indicating the positive direction when the current reversing control switch is in the UP position. If this is not the case, simply reverse the magnet voltage leads or the magnet supply leads at the vapor cooled current lead connection. This note applies to systems utilizing an energy absorber.*

Quench Detection - This protection circuit continuously monitors magnet current (when enabled) and in the event of magnet quench, quickly ramps the power supply output to zero. This circuit can be reset by placing the switch in the OFF/RESET position momentarily and then returned to the QUENCH DETECTION position. This protection feature can be disabled if magnet voltage transients cause the protection circuit to operate when the magnet has not quenched. To disable this feature put the switch in the down position.

Persistent Switch Heater - The heater is controlled by the key switch. The POWER LED indicates the control circuit is operational but does not indicate heater operation. The OUTPUT LED indicates current is being supplied to the heater; i.e. the LED is on when the heater is energized thereby removing the magnet from persistent mode.

The AMI programmer incorporates a unique stability circuit which makes it compatible with many power supplies which could not previously be used with superconducting magnets. A current programmer includes the power supply in a feedback loop. Not only do various power supplies have different characteristics but the load can be resistive (including a short circuit) highly inductive, or a combination (series leads, parallel persistent switch). A circuit which achieves stability (no current oscillations) under all these conditions is difficult to achieve. The Models 410, 411, and 412 have been designed to achieve this goal. It has been tested with the HP 6260B power supply as well as the Power Ten 10100 switching power supply. Other power supplies are expected to work equally well. It should be mentioned that the programmer cannot improve on the natural dynamic noise level of the power supply.

Should any instability occur, the Model 410-412 is equipped with an adjustable damping circuit. Refer to the Troubleshooting Section VII for more information.

V. OPERATION

1. **System Test**:

   Prior to connecting the power supply cables to the magnet current leads, it may be desired to preset your magnet controller current limit to the current that corresponds to the rated central field (i.e. rated current) and check to ensure the controller operates properly. The first time you use the programmer it is best to test the system on a short circuit rather than a magnet. This can be done as follows:

   a. Ensure the magnet power supply is de-energized and short the output leads from the power supply together securely.

      NOTE: *If you have an energy absorber in your system you will short the output leads of the energy absorber instead of the power supply.*

   b. Ensure the key operated PERSISTENCE SWITCH HEATER switch is OFF.

   c. Set the VARIABLE ramp rate potentiometer on 10 and the current control switch in the DOWN position.

   d. Set the CURRENT LIMIT potentiometer to the rated current as indicated on you AMI magnet data sheet.

   e. Turn on power to the magnet programmer.

   f. Turn on power to the power supply.

   g. Place the CURRENT CONTROL switch to the UP position. The current indication should rapidly increase to the approximate rated current.

   h. Adjust the current to the specified value by fine tuning the CURRENT LIMIT potentiometer. The current limit is now set and you are assured the power supply/magnet programmer is working properly.

   i. Place the CURRENT CONTROL switch to the DOWN position to ramp the current to zero.

   j. Turn off power to power supply and then to the magnet programmer.

      CAUTION: *Always energize the programmer first, then the power supply upon system startup and always deenergize the programmer last on system shutdown to allow the programmer to always have control of the system. Not doing so could result in* *voltage/current spikes introduced in the magnet system with could produce undesirable results.*

k. Reconnect the power leads to the vapor cooled current leads.

2. ***Mode A* (normal mode) operation:**

a. Place the Computer-Manual switch in the MANUAL position.

b. Place to Up-Pause-Down switch in the DOWN position.

c. Adjust the Voltage Limit to 10, Ramp Rate and Current Limit as desired.

d. Use the charging voltage and inductance in the specification sheet to calculate the rate from the equation $V = L\ dI/dt$.

e. Energize the programmer and the power supply.

> *<u>CAUTION:</u> Always energize the programmer first, then the power supply upon system startup and always deenergize the programmer last on system shutdown to allow the programmer to always have control of the system. Not doing so could result in voltage/current spikes introduced in the magnet system with could produce undesirable results.*

f. Enable the quench detection circuit (if desired).

g. Ramp the magnet up or down by using the Up-Pause-Down switch.

h. The various switches (Ramp Rate Range, Ramp Rate, Current Limit, and Up/Down/Pause) can be changed at any time. Care should be exercised not to set the current limit or ramp rate to higher values than can be tolerated by the magnet.

i. To change the current setting (and field) place the ramp up-down switch in the PAUSE position. Set the rate range switch and rate dial to the charge rate desired and the current limit to the desired point. Placing the ramp switch to the UP position will cause the current to ramp up at the desired rate. The current can be stopped, and held at any time by placing the ramp switch to PAUSE, or can be ramped down at the chosen rate by flipping the switch to the DOWN position. The desired rate is maintained provided the charge and discharge voltages demanded by the superconducting coil ($V = L\ dI/dt$) are within the capabilities of the power supply - diode system. If the ramp switch is left in the UP position the current will ramp up to the current limit where it will be locked in to a stable current mode.

3. ***Mode B* (computer mode) operation:**

a. Connect a cable from your computer interface to the Computer Control connector on the back of the programmer. The pin connections to the programmer are shown in Figure 6.

b. Place the Computer-Manual switch in the COMPUTER position.

c. Set the voltage limit potentiometer to 10.

d. Energize the programmer and power supply.

> *CAUTION:* *Always energize the programmer first, then the power supply upon system startup and always deenergize the programmer last on system shutdown to allow the programmer to always have control of the system. Not doing so could result in voltage/current spikes introduced in the magnet system with could produce undesirable results.*

e. Enable the quench detection circuit (if desired).

f. Set the ramp rate RANGE switch to the correct rate. Note that the computer does not control this switch. It must be set manually.

g. The programmer is now under computer control. To control the magnet current the computer must furnish analog signals (0-5 volts) to the Ramp Rate connections (J5 Pins 1 & 14) and the Current Limit connections (J5 Pins 2 & 15). Five volts on the ramp rate pins produces 0.1, 1.0, or 10.0 A/S depending on the setting of the ramp rate range switch on the programmer. Five volts on the current limit pins will set the current limit to full scale current for the system. Intermediate voltages produce scaled values for the ramp rate and current limit. In this mode the external Up/Down/Pause switch is inoperative because it has been disconnected internally and placed in the "up" mode. This means that the magnet current always ramps up or down to the value corresponding to the voltage signal from the computer. An opto-isolator signal is available from the programmer (pins 5 & 18) which can be read to indicate when the current limit has been reached. An analog voltage is supplied by the programmer (0-5 volts, Pins 19 & 7) which can be read directly by the computer to indicate the current at any time. One can approximate any current function within the range of the magnet/power supply system by a sequence of straight lines controlled by the computer supplied ramp rate voltage and current limit voltage.

4. ***Mode C* (internal ramp generator function) operation:**

a. Set up the programmer and power supply as described for mode A operation.

b. Disconnect jumper W2 on the printed circuit board.

c. A linear ramp voltage controlled by the ramp range switch, the variable ramp rate potentiometer, and the Up/Down/Pause switch is available between the green RAMP OUT and the black COMMON terminals on the rear panel of the programmer.

d. If your magnet is equipped with a persistent switch be sure that the persistent switch heater power supply is turned on to charge the magnet.

5. (Model 412) **Magnet Persistent Mode Operation**:

   a. Record the current displayed on the Magnet Current meter.

   b. Lock the current against the current limit by leaving the current control switch in the UP position when the desired current limit has been established. Wait for the inductive voltage across the magnet to reach zero. If the voltage is measured any place except at the magnet terminals, it is more difficult to tell when the inductive voltage is zero because the voltage drop in the lead system is added to the inductive voltage.

   c. Turn the key operated switch to the OFF position. When the persistence switch heater is turned off you should allow the switch to cool off for approximately 30 seconds. This is a safe number. Actually, most AMI persistent switches cool adequately in a few seconds.

   d. A more reliable technique for ramping the current to zero is to program the current to zero with the ramp down switch. The ramp rate range switch can be increased to hasten the discharge. The voltage across the magnet should remain zero. A negative voltage during magnet discharge means the current is decaying and the magnet is not in the persistent mode. In this case, ramp the current back to the desired value and try again.

   e. To return to the programmed control mode of operation ensure the current limit is set to the value recorded when you switched into the persistent mode.

      NOTE: *The best method is to not have moved the current limit setting after switching to the persistent mode.*

   f. Turn the power supply back on and put the Up/Down/Pause switch in the Up position. The current indication should begin ramping up while the voltage across the magnet remains zero.

      NOTE: *If You switch the ramp selector to "10" to decrease the time to ramp the current to the desired value. Be sure to return the range switch to the appropriate setting before switching out of the persistent mode.*

   g. When the current reaches the desired value turn the persistent switch heater ON. There will be a 10 to 15 second time delay as the switch heats up. You may see a small voltage across the magnet as the current of the magnet and power supply match up but this should quickly decay to zero.

VI. CALIBRATION

NOTE: *This instrument was calibrated at the factory and should require no further adjustment for many years. The following* *information is furnished in the event changes are desired or due to aging of the components causing calibration errors.*

Current Shunt - The calibrations of the programmer are based on the use of a 100 ampere/100 millivolt current shunt, however, shunts of other sizes can be used if the scale factor F = (shunt amps/volt)/(100/0.1 amps/volt) is applied to the current rates and current limits. For example, to use a 50 amp, 0.1 volt shunt, F = (50/.1)/(100/.1)-.5. Thus 10 amp/sec rate is now 0.5 x 10 amp/sec = 5 amp/sec and the full scale current limit is 0.5 x 100 amp = 50 amperes.

►***WARNING:*** *This calibration procedure is to be performed only by trained service personnel familiar with electrical safety precautions and proper energized electrical safety procedures. The Models 410-412 contains high voltages capable of producing life-threatening electrical shock. Do not perform any operations on any AMI equipment with the cover removed unless qualified to do so and another person qualified in first aid and CPR is present.*

1. Deenergize the instrument by disconnecting the power plug from the power receptacle.
2. Disconnect the programmer from any power supplies.
3. Remove the instrument cover.
4. Verify the main PCB jumper configuration is as follows:

   W1 .... JUMPERED
   W2 .... JUMPERED
   W3 .... JUMPERED
   W4 .... OPEN
   W5 .... JUMPERED
   W6 .... JUMPERED
   W7 .... JUMPERED
   W8 .... OPEN
   W9 .... OPEN
   W10 .... OPEN
   W11 .... OPEN

5. Adjust the STABILITY potentiometer P7 fully counter-clockwise.
6. Place a shorting jumper across the CAL test points on the PCB.
7. Plug in the line cord to the proper voltage source.
8. Place the front panel COMPUTER/MANUAL switch in the MANUAL position.
9. Place the POWER switch to the ON position.
10. Ensure the power LED and the DVM on the front panel are lit.

11. Look for any unusual signs of component heating on the PCB
12. Measure the power supply outputs on the PCB at TP +15V, -15V, and +5V with respect to COMMON.
13. Connect a voltmeter between TP7 and COMMON. Adjust the input NULL potentiometer P2 until the meter reads 0.000 volts.
14. Connect the voltmeter between TP13 and common. Adjust the CURRent LIMIT pot P12 to obtain 5.000 volts.
15. Connect the voltmeter between TP14 and common. Adjust the VOLTage LIMIT pot P11 to obtain 10.000 volts.
16. Connect the voltmeter between TP15 and common. Adjust the RAMP RATE pot P10 to obtain 5.000 volts.
17. Place the front panel CHARGE RATE RANGE switch to 10 amperes/second.
18. Place the front panel CURRENT CONTROL switch in the UP position.
19. Turn the front panel VOLTAGE LIMIT potentiometer fully CW (10.0).
20. Connect the voltmeter between TP5 and common. Adjust the VOLTage LIMIT pot P11 to obtain +10.000 volts.
21. Connect the voltmeter between TP3 and common. Adjust the output voltage PROGRAM OUT pot P6 to obtain 10.000 volts if the programmer is in a system with a HP 6260B power supply. If the programmer is in a system with a switching power supply, adjust P6 to obtain 5.000 volts.

    NOTE: *Refer to the power supply manual for the proper control voltage.*

22. Place the front panel CURRENT CONTROL switch in the DOWN position.
23. Connect the voltmeter between TP11 and common. Adjust the ZERO LOCK potentiometer P8 to obtain 0.000 volts.
24. Deenergize the programmer.
25. Remove the shorting jumper across the CAL test points on the PCB.
26. Connect the programmer to the power supply and energy absorber (if possible). Ensure the PROGRAM OUT and CURRENT SHUNT terminals on the rear panel are properly connected to the power supply and current shunt as described in the Installation section of this manual.
27. Short the current leads of the power supply system.

28. Connect a precision millivoltmeter across the current shunt.

29. Energize the system as described in the Operation section of this manual.

30. Place the front panel CURRENT LIMIT POT to the fully CW position.

31. Place the front panel CURRENT CONTROL switch in the UP position.

32. After the current has reached the system maximum (typically 100 Amperes), adjust the GAIN potentiometer P1 until the millivoltmeter reads exactly 100mV.

33. Place the front panel CURRENT CONTROL switch in the DOWN position.

34. Move jumper W3 to W4 on the PCB.

35. Remove jumpers W5 and W6 on the PCB.

36. Connect the voltmeter between TP11 and common. Use the front panel CURRENT CONTROL switch to adjust the voltage to approximately 1 volt. Leave the switch in the pause position after adjustment.

37. Move the positive lead of the voltmeter to the right side of C9 or C10. (This is the side of the integrating capacitors near U12 & U13).

38. Adjust the DRIFT potentiometer P9 until the voltmeter reads 0.000 volts.

39. Disconnect the voltmeter.

40. Move jumper W4 to W3 on the PCB.

41. Replace jumpers W5 and W6 on the PCB.

42. Perform the following if the system is controlled by computer via a MAXUS interface.

    a. Connect the MAXUS AIO-2000 interface unit to J5 on the rear panel of the programmer.

    b. Switch the front panel COMPUTER/MANUAL switch to the COMPUTER position.

    c. Set the ramp rate of the programmer to 1.0 A/S via the MAXUS.

    d. Set the current limit of the programmer to 0.0 via the MAXUS.

    e. Connect a precision millivoltmeter across the current shunt.

    f. Adjust INPUT NULL potentiometer P2 for 0.000 on the millivoltmeter. This adjustment should correspond to zero voltage on the power supply.

    g. Read back the current via the MAXUS. Adjust ZERO OFFSET potentiometer P3 until the MAXUS reads back 0.000 current.

h. Ramp to 100.0 Amps via the MAXUS.

i. Adjust GAIN potentiometer P1 until the millivoltmeter reads 100.0 mV.

j. Adjust ANALOG OUT potentiometer P4 until the computer via MAXUS reads 100.0 Amps.

k. Adjust DVM OUT potentiometer P5 until the programmer front panel current meter reads 100.0 Amps.

l. Repeat steps a. through l. until no further adjustments are necessary.

m. Place the front panel COMPUTER/MANUAL switch in the MANUAL position.

43. Place the front panel CURRENT CONTROL switch in the UP position.

44. At maximum current, adjust CURRENT LIMIT potentiometer P12 until the millivoltmeter reads 100.0 mV.

45. Deenergize the system and reinstall the cover.

The calibration procedure is complete.

VII. TROUBLESHOOTING

1. No power indication:

    a. Ensure programmer is plugged into the proper power receptacle and power is available at the receptacle.

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

    b. Check to be sure the power switch is on.

    c. Ensure line fuse is not blown.

    d. Ensure all connections are secure and there are no broken wires, cold solder joints, shorts, etc.

2. Erratic Operation:

    a. Ensure all wires are connected to the proper connectors.

    b. Ensure the magnet power supply is in the voltage programming mode.

    c. Non-linear magnet ramping can be caused by attempting to exceed the positive or negative voltage available for the magnet from the power supply. The voltage limit function will also result in non-linearities.

    d. Ensure the local controls on the power supply are at the maximum setpoint to allow the programmer to have control.

    e. Polarity of the programmer output voltage and the current shunt input voltage must be as indicated on the rear panel of the programmer. Twisted, shielded pairs of wires should be used for both sets of voltage leads.

    f. Ground loops can cause a variety of problems. The black OUTPUT terminal is the common point for the programmer and can be grounded to the system ground if necessary. Avoid more than one ground in the system.

3. Failure to program (ramp up):

    a. Current limit set to zero.

    b. Improper polarity (see #2 above).

c. Ramp rate set at zero.

d. Voltage limit set at zero.

e. Open or high resistance current path (e.g. coil not superconducting).

f. Programmer tracking circuit improperly adjusted.

4. Current/Voltage Oscillations:

a. Oscillations can be caused by a noisy or unstable power supply, misalignment of the programmer, or phase shifts in the system.

b. Should any instability occur, the Model 410 is equipped with an adjustable damping circuit.

NOTE: Refer to the precautions of the Calibration Section VI. before proceeding with this adjustment.

The instrument is adjusted for minimum damping (STABILITY adjustment potentiometer (P7) fully counter clockwise) when shipped from the factory.

While the power supply is oscillation, slowly adjust the STABILITY pot (P7) clockwise until the oscillations stop. Do not adjust the pot more clockwise than is necessary to stop the oscillations. Always adjust the stability to the minimum value because the greatest programming accuracy is achieved with the adjustment fully counter clockwise.

It is now necessary to re-adjust the CURRENT LIMIT trimmer (P12) on the circuit board to ensure that a setting of 10.0 on the CURRENT LIMIT dial on the face of the instrument (or an input voltage of 5.0 volts from the computer control system) will produce exactly 100 amperes.

5. Unable to enter persistent mode operation:

The switching power supply produces a higher noise level than the HP pass transistor supply. This should not normally be a problem since the high inductance of the superconducting magnet is a good filter. The place where a potential problem exists is related to persistent switch operation. If the power supply ripped is too large it might produce enough eat in a persistent switch to prevent the switch from returning to the superconducting state, i.e., you might not be able to lock the magnet into the persistent mode. AMI persistent switches are fast acting well cooled devices and have been found to work with the Power Ten switching power supplies.

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

VIII.WARRANTY

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

IX. RETURN AUTHORIZATION

Items to be returned to AMI for repair (warranty of otherwise) require a return authorization number to ensure your order will receive proper attention. Please call an AMI representative at (615)482-1056 for a return authorization before shipping any item back to the factory.