AUTOMATED POWER CONTROLLER
FOR
HOLLOW CATHODE
END HALL ION SOURCE
EHC25020A

Kaufman & Robinson, Inc.
1306 Blue Spruce Drive
Fort Collins, CO 80524
Tel: 970-495-0187, Fax: 970-484-9350
Internet: www.ionsources.com

March 2014
VERSION B

CONTENTS

Figures

Tables

1. SAFETY

Caution: High Voltage. Only technically qualified personnel should install, maintain, and troubleshoot the equipment described herein.

The Auto Controller and power supplies for the End Hall ion source must be installed in a grounded 19-inch (483 mm) rack mount cabinet before operation.

2. GENERAL DESCRIPTION AND SPECIFICATIONS

The automated package combines modular power supplies and automatic control for operating an End-Hall ion source. The auto controller is designed for use in a standard 19-inch (48 cm) rack mount cabinet. The Auto Controller, Keeper Power Supply, Bias Power Supply, Discharge Power Supply and Gas Controller are included in the standard package along with the associated interconnection and power cables.

The operating specifications, weight and dimensions of each controller are outlined in the following table.

This section gives a general overview of the Automated package with more detailed information in the later sections of this manual.

Table 2-1 Controller Specifications

	Nominal Input voltage	Maximum Input Current	Maximum Output	Weight	Height x Depth
Auto Controller	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ, 50-60 Hz	0.75 A 0.38 A	+/- 15 V, 500 mA DC	3.0 kg (8 lbs)	4.4 x 53 cm (1.75 x 21 in.)
Keeper Power Supply	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ, 50-60 Hz	14 A 7.5 A	800 V, 2 A DC Power	7.27 kg (16 lbs)	4.5 x 53 cm (1.75x 21in.)
Bias/Emission Power Supply	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ, 50-60 Hz	14 A 7.5 A	120 V, 15 A DC Power	7.27 kg (16 lbs)	4.5 x 53 cm (1.75x 21in.)
Bias/Emission Power Supply	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ, 50-60 Hz	14 A 7.5 A	120 V, 15 A DC Power	7.27 kg (16 lbs)	4.5 x 53 cm (1.75x 21in.)
Discharge Power Supply	185-480 V, 3Φ, 50-60 Hz	28 A*	250 V, 20 A DC	12.4 kg (27.5 lbs)	8.9. x 53 cm (3.5x 21in.)

*The maximum discharge power supply output is 5,000 watts at 40˚C ambient air temperature but can be set to a user configurable limit, usually 3,000 watts, depending on the application. Contact KRI for directions on implementing a power limit above 3,000 Watts Note: The discharge supply will scale over limit wattages back to the set power limit; scale down time is dependent upon the exceeding wattage.

2.1 Auto Controller

The Auto Controller is designed to be installed in a standard 19 inch rack mount cabinet and is shown in figures 2-1, 2-2a, 2-2b, and 2-2c along with the keeper, Bias and discharge power supplies. The controller communicates with the power supplies through a RS-485 interface. A front panel switch allows selection of either local or remote mode operation. The End Hall ion source can be controlled from the front panels when local mode is selected. When remote mode is selected, the End Hall ion source can be completely controlled via connections to the rear panel. Alternately, programs selected from the front panel can be enabled or disabled from the rear panel when remote mode is selected. Sockets are installed on the rear panel for remote operation using either RS-232 or an Analog interface.

The Auto Controller also interfaces with up to four mass flow controllers using cables that connect to the rear panel. Four relay contacts are also available on the rear panel if additional positive shut off valves are desired for the gas feed system. Three of the gas channels are available for use with the ion source, while gas channel 4 is dedicated to the hollow cathode,

The Auto Controller is connected to the Keeper, Bias and Discharge power supplies through an RS 485 interface. When the RS-485 interface is not connected the Auto Controller functions as a stand-alone power supply and readout for four mass flow controllers.

2.2 Keeper Power Supply

The Keeper Power Supply is designed to be installed in a standard 19 inch rack mount cabinet and is shown in figures 2-1 and 2-2, 2-2a, 2-2b, and 2-2c along with the Auto Controller, and the Bias\Emission and Discharge power supplies. The Keeper Power Supply provides voltage and current to the Hollow Cathode Electron Source (HCES) for igniting the hollow cathode and keeping the cathode hot for thermionic emission. This power supply communicates to the Auto Controller through a RS-485 interface.

Additional information can be found in the individual manual for the Keeper Power Supply.

2.3 Bias/Emission Power Supply

The Bias Power Supply is designed to be installed in a standard 19 inch rack mount cabinet and is shown in figures 2-1 and 2-2 along with the Auto Controller, and the Keeper and Discharge power supplies. The Bias Power Supply provides a negative voltage bias to the hollow cathode after it is ignited by the Keeper Power Supply and controls the electron current emitted from the HCES. This power supply communicates to the Auto Controller through a RS-485 interface. The power controller package will generally include two Bias Power Supplies. These supplies are operated in parallel, which means that the displayed value on the front panel will each be equal to one-half of the total bias current. Occasionally, depending upon the application, two Emission Supplies will be used in place of the two Bias Supplies. The Emission Supplies have an adjustable voltage setpoint that is not normally required for most applications.

Additional information can be found in the individual manual for the Bias/Emission Power Supplies.

2.3 Discharge Power Supply

The Discharge Power Supply is designed to be installed in a standard 19 inch rack mount cabinet and is shown in figures 2-1 and 2-2 along with the Auto Controller and the Keeper and Bias power supplies. The Discharge Power Supply provides voltage and current to the anode of the End-Hall ion source. This power supply communicates to the Auto Controller through a RS-485 interface.

Additional information can be found in the individual manual for the Discharge Power Supply.

2.4 Gas Control

The Auto Controller or Mass Flow Controller(s) (MFC) are supplied when ordered as a complete system. The MFC(s) are connected to the gas feed for the ion sources as close as possible to the gas feedthrough on the vacuum system. Up to four mass flow controllers can be attached to the Auto Controller, although channel four is dedicated to the hollow cathode. The gas flows can be set as a constant ratio or they can be set independently.

The Auto Controller can be used with a variety of mass flow controllers. However, the cables may vary depending on the mass flow controller provided in the order. The pin

descriptions for the female DB-15 connectors on the back of the Auto Controller are given below in table 2-2.

Table 2-2. Pin descriptions for the DB-15 MFC connectors on the Auto Controller.

Pin number	Description
1	Command Common. Return for 0-5 volt output to MFC on pin 8.
2	Mass flow read back from MFC. 0-5 volt signal from the MFC referenced to pin 10.
3	No contact.
4	Valve off. Connected to common when MFC setpoint is set to zero or when unit is in the standby mode, otherwise floated.
5	+15 volts DC for MFC supply voltage, referenced to pin 9.
6	- 15 volts DC for MFC supply voltage, referenced to pin 9.
7	No contact.
8	Setpoint out to MFC. 0-5 volts, referenced to pin 1.
9	Common for MFC supply voltages on pins 5 and 6.
10	Read back common. Reference for the 0-5 volt mass flow readback from the MFC on pin 2.
11	No contact.
12	No contact.
13	No contact.
14	Chassis ground
15	No contact.

Fig. 2-1. Front view of High Power Automated Controller

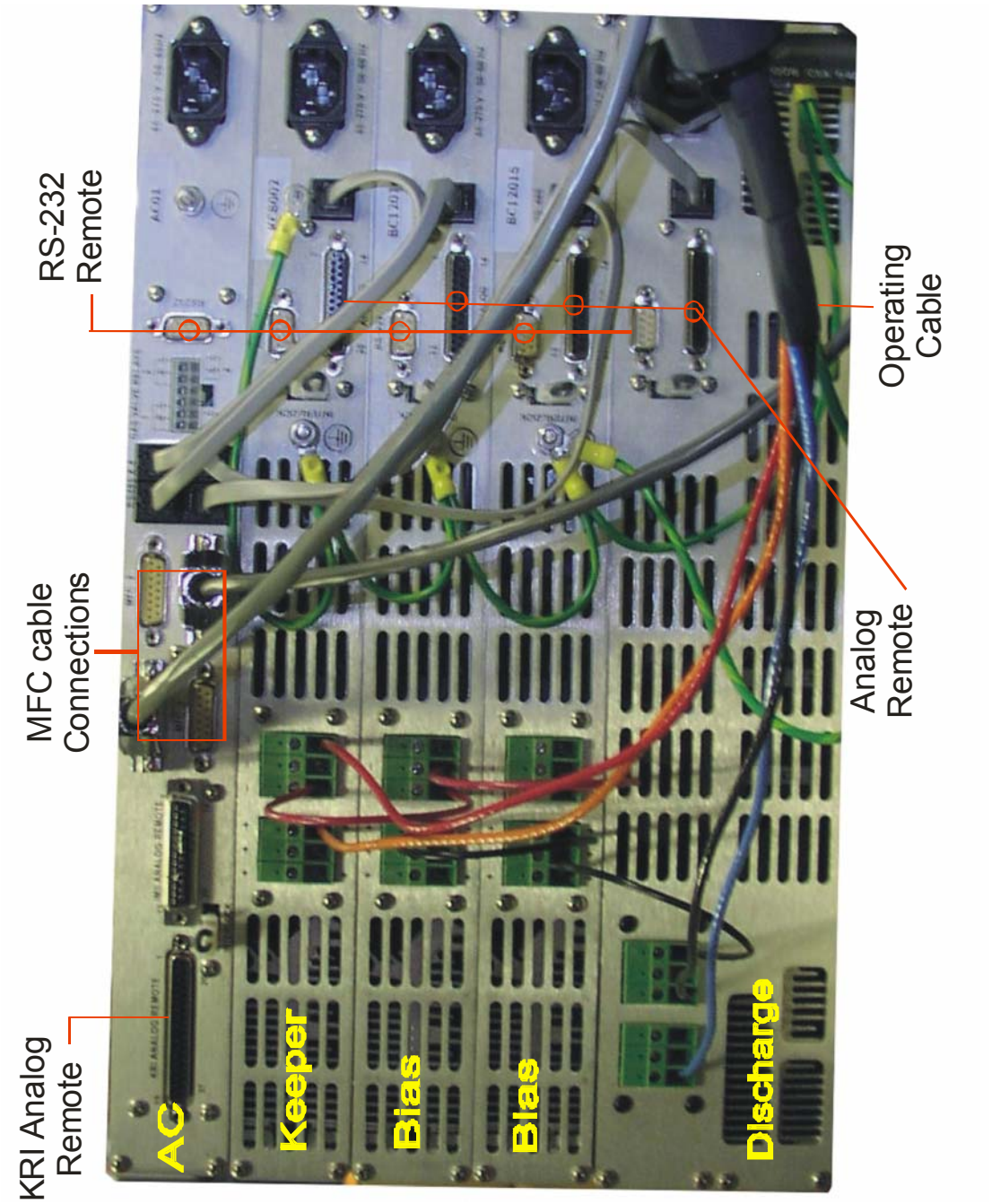
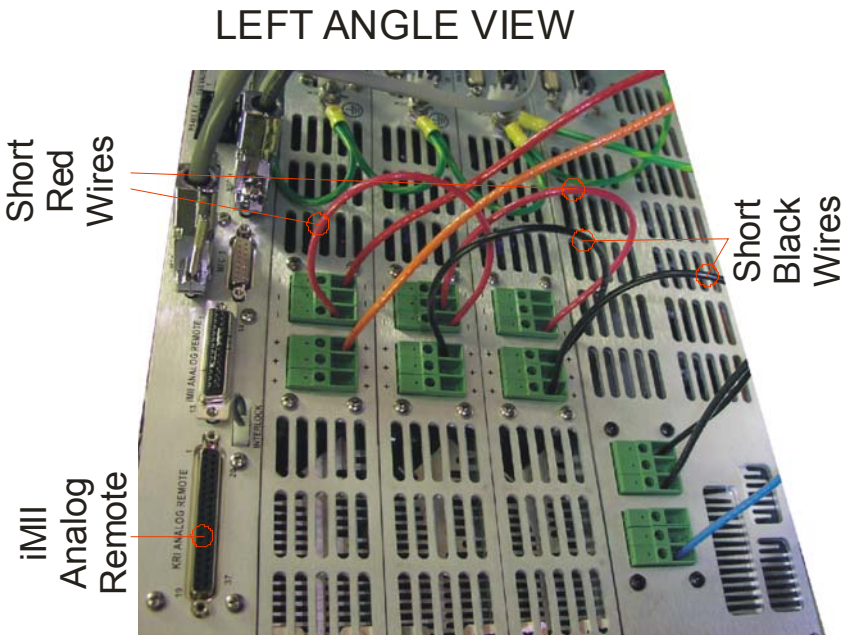


Fig. 2-2a. Rear view of High Power Automated Controller

b)



c)

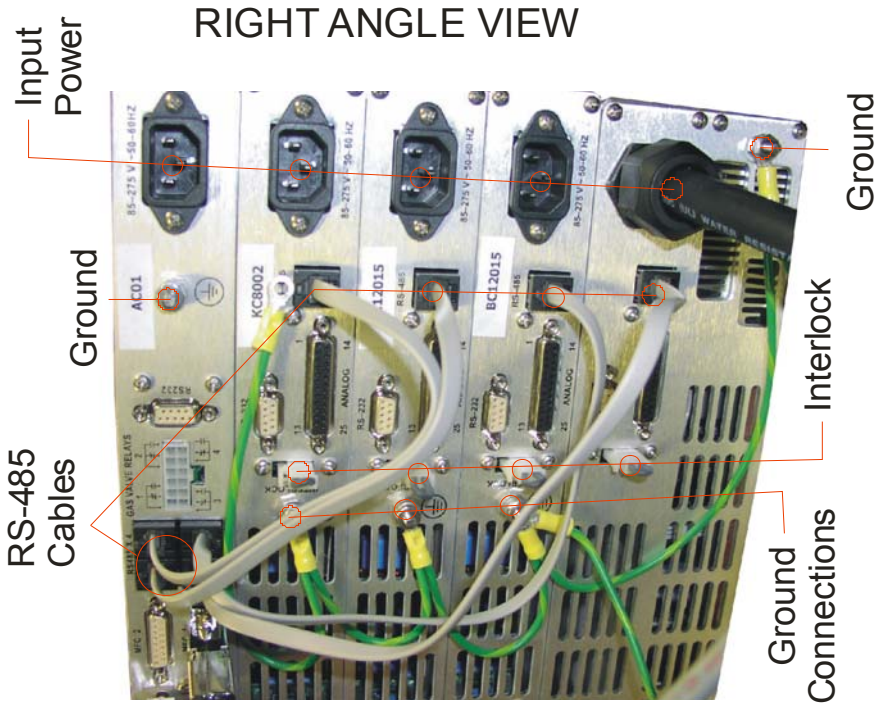


Fig. 2-2b & c. Rear view of High Power Automated Controller

3. INSTALLATION

This section describes how to install the Kaufman & Robinson, Inc., KRI® Controller package for the hollow cathode version of the End Hall Ion Source.

3.1 Unpack

Unpack the Controller package for the End Hall Ion Source. Prior to shipment, the Controller was tested to insure quality and verify the standard range of operation. As soon as the Controller has been completely removed from all packing materials, a visual inspection should be made to determine if there has been any damage to the components during shipment. Use the packing lists provided to confirm the completeness of order. If any damage has occurred, contact Kaufman & Robinson, Inc., in addition to the shipping company, to report the damage - see Section 8. Retain packaging materials for any future shipments.

Table 3-1 is an inventory list for the controller package. The inventory list is for the standard package so some items may or may not be included depending on the particular order. Refer to the packing slip for the part numbers. For any questions or discrepancies concerning either the inventory or shipping list, see Section 8 to contact Kaufman and Robinson, Inc. Refer to Section 2 – General Description and Specifications for additional information about the controller.

Table 3-1 Controller Inventory List

Quantity	Description
1	Auto controller
1	Keeper Power Supply
2	Bias Power Supply
1	Discharge Power Supply
4	Input Power cables
2	Red wire
2	Black wire
1	Green/Yellow daisy chain ground wire.
1	Operating cable, 6 m (20 ft) cable (if purchased)
4	Interface cables, RS-485

3.2 Install in Rack Mount Cabinet

The Controller is designed to be mounted in a standard 19-inch (48 cm) rack mount cabinet. To assure that the power cable that came with each controller is connected to that controller, the power cables can be connected as each controller is installed in the cabinet. **Do not connect to input power before the installation is complete.** The input power requirements are given below in table 3-2. Universal single phase 50-60 Hz input power of 85 to 275 volts can be used for all power supplies except the discharge power supply, so no modification is required to use either a nominal 115 or 208-230 volt input.

Table 3-2. Input power requirements.

Module	Nominal Input Voltage	Maximum Input Current
Auto Controller	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ, 50-60 Hz	0.75 A 0.35 A
Keeper Power Supply	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ 50-60 Hz	14 A 7.5 A
Bias/Emission Power Supply	115 V, 1Φ, 50-60 Hz 208-230 V, 1Φ 50-60 Hz	14 A 7.5 A
Discharge Power Supply	185-480 V, 3Φ, 50-60 Hz	28 A

The Auto Controller, Keeper Power Supply, Bias Power Supplies and Discharge Power Supply should be mounted one above the other in the cabinet. See Fig. 3-1 for the relative locations of the individual rack mounted units. The wiring and cables may not reach all the controller connections if installed in a different order.

3.3 Ground Connections

An earth ground connection is required for both safety and correct operation. Earth ground should be connected to the vacuum chamber in which the ion source is to be operated as well as the cabinet in which the Controller is installed. Make sure that qualified technical personnel make these ground connections. These ground connections are independent of the ground connections described below in section 3.4.

3.4 Connections Between Controller Components

The connections between Controller components are shown in Fig. 3-2, which shows the rear panels of the Auto Controller, and the Keeper, Bias and Discharge power supplies. The individual connections required are given below:

- If the 6 meter (20 ft.) input power supply cables were not connected to the individual power supplies when they were installed in the cabinet, connect them now. Use plugs that will match the input power sources. **Again, do not connect the input power before the installation is complete.**

- Attach the 4 pin (female) plug connector of the 6 meter (20 feet) operating cable to the connector on the electrical feedthrough. The connections for the other end of this cable are described below.

- Insert the end of the operating cable **BLUE** wire into one of the (**+**) positive connectors located on the rear panel of the Discharge Power Supply and tighten the screw above the appropriate connector.

- Insert the end of the operating cable **BLACK** wire into one of the (**-**) negative connectors located on the rear panel of the Discharge Power Supply and tighten the screw above the appropriate connector.

- Insert the end of the operating cable **RED** wire into one of the (**-**) negative connectors located on the rear panel of the Keeper Power Supply and tighten the screw above the appropriate connector.

- Insert the end of the operating cable **ORANGE** wire into one of the (**+**) Positive connectors located on the rear panel of the Keeper Power Supply and tighten the screw above the appropriate connector.

- Insert one end of the short **RED** wire into one of the (**-**) negative connectors located on the rear panel of the Keeper Power Supply and tighten the screw above the appropriate connector. Insert the other end into the top Bias Power Supply (**-**) negative connector and tighten the screw above the appropriate connector.

- Insert the other short **RED** wire into one of the (**-**) negative connectors located on the rear panel of the top Bias Power Supply and tighten the screw above the

appropriate connector. Insert the other end into the bottom Bias Power Supply (**-**) negative connector and tighten the screw above the appropriate connector.

- Insert one end of the short **BLACK** wire into one of the (**+**) positive connectors located on the rear panel of the top Bias Power Supply and tighten the screw above the appropriate connector. Insert the other end into the bottom Bias Power Supply (**+**) positive connector and tighten the screw above the appropriate connector.

- Insert one end of the short **BLACK** wire into one of the (**-**) negative connectors located on the rear panel of the Discharge Power Supply and tighten the screw above the appropriate connector. Insert the other end of the short **BLACK** wire into one of the (**+**) positive connectors located on the rear panel of the top Bias Power Supply and tighten the screw above the appropriate connector.

- Attach the ring terminal end of the operating cable **GREEN/YELLOW** wire into the ground stud of the Discharge Power Supply.

- Attach the ground connections using the **GREEN/YELLOW** wire with the five ring terminals as follows; Connect the five ring terminals to the four ground studs on the Auto Controller rear panel, the Keeper Power Supply rear panel, the two Bias Power Supplies rear panel and the Discharge Power Supply rear panel. Tighten the nuts on the ground studs. Connect the remaining green striped yellow wire to the chassis system ground for the electrical cabinet that the power supplies are installed in.

- Attach the four RS-485 cables to the connector labeled “RS-485 X 4” located on the back panel of the Auto Controller as shown in figure 3-2. The RS-485 connectors are not device specific, so they can be plugged into any of the RS-485 connectors.

- Attach the other ends of the four RS-485 cables to the connectors labeled “RS-485” located on the power supply back panels, one for the Keeper, two for the Bias and one for Discharge as shown in figure 3-2.

- Attach the MFC cable to the connector labeled “MFC 1” located on the back panel of the Auto Controller. Attach the other end to the MFC for the ion source. The pin descriptions for the DB-15 Female connectors are shown below in table 3-3.

- Attach any additional ion source MFC cables to the connectors labeled “MFC 2”, “MFC 3” located on the back panel of the Auto Controller. Attach the other ends of these cables to the corresponding MFC’s for the ion source.

- Attach the hollow cathode MFC cable to the connector labeled “MFC 4” located on the back panel of the Auto Controller. Attach the other end to the MFC for the hollow cathode. The pin descriptions for the DB-15 Female connectors are shown below in table 3-3.

- The mass flow controller is defined by the ion-source application. The mass flow controller should be mounted as close as possible to the vacuum chamber. See the MFC manual. If an additional positive shut off valve is to be used with the MFC’s, they should be located directly downstream of the MFC (between the MFC and the vacuum chamber wall). Additionally, if an in-line gas purifier is used in the hollow cathode gas line, it should be located just upstream from the mass flow controller.

- There is a two pin interlock connector located on the back of the Auto Controller. The unit comes supplied with a jumper installed in the interlock connector. The Auto Controller disables the outputs of the power supplies if this contact is open. If a system interlock is used, a separate isolated contact should be connected to each of the five interlock connectors.

- If remote control of the auto controller is used, that cable can be attached at this time to the female DB-25 connector, the female DB-37 connector or the female DB-9 connector. These remote interfaces require knowledge of the ion source operation, which is given in the next two sections of this manual. The detailed descriptions for remote control are in Section 6 REMOTE/AUTOMATED CONTROL of this manual.

- The connections between the pressure regulators and the flow controller valves should be made with *clean (passivated or hydrocarbon free)* stainless steel tubing, with all fittings properly installed. **To avoid contamination of the gas, plastic tubing should not be used**

Table 3-3. Pin descriptions for the rear panel DB-15 female MFC output connectors.

Pin Number	Description
1	Common for 0-5 volt setpoint.
2	0-5 V flow read back signal from MFC, referenced to pin 10.
3	Not used.
4	Valve off. Connected to common when the setpoint flow is set to zero or when the Auto Controller is in standby, otherwise floated.
5	+15 V, referenced to pin 9.
6	-15 V, referenced to pin 9.
7	Not used.
8	0-5 V setpoint out to MFC, referenced to pin 1.
9	Power common for ± 15 V.
10	Common for read back signal.
11	Not used.
12	Not used.
13	Not used.
14	Chassis Ground.
15	Not used.

3.5 Connect Controller to Ion Source

If the Ion Source has not been installed in the vacuum chamber, do so now, using the Installation/Inspection description in the ion source manual. The ion source installation procedures cover installation of the ion source, vacuum cables, gas tubing inside the vacuum chamber, as well as electrical and gas feedthroughs in the wall of the vacuum chamber. Once installed, connect the operating cable to the electrical feedthrough.

- As the final installation step, turn off the front panel power switches on the Auto Controller, Keeper Power Supply, Bias Power Supplies, and Discharge Power Supply and then plug the power cables of the individual controllers into appropriate input power sources. See table 3-2 above for input power requirements.

The installation for the automated power controller is now complete.

Fig. 3-1. Front view of High Power Automated Controller

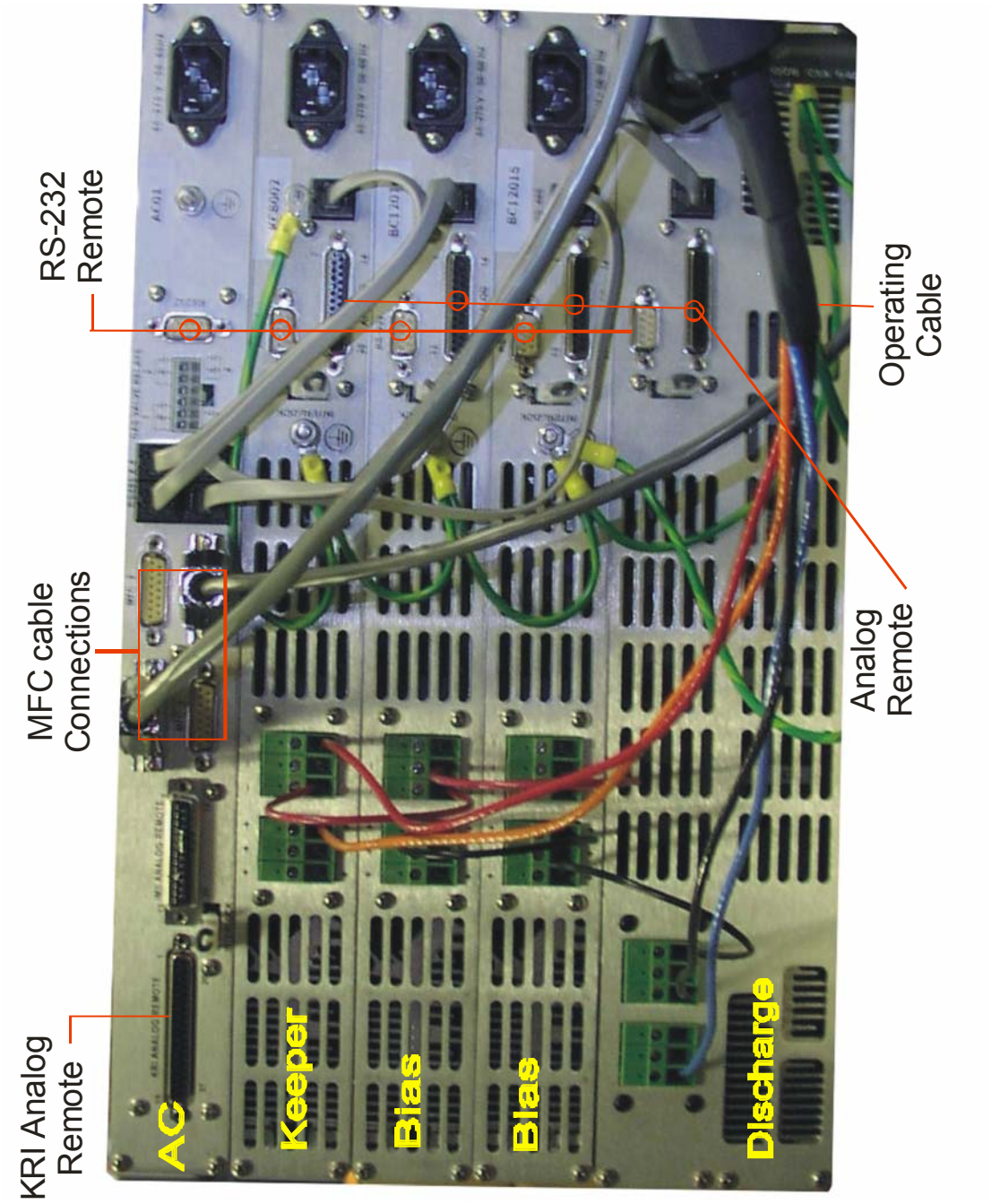
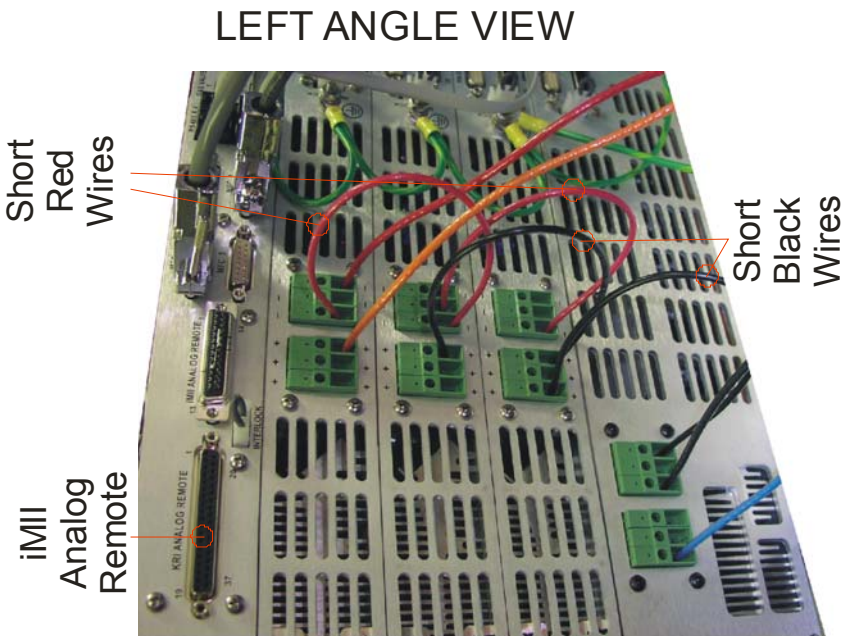


Fig. 3-2a. Rear view of High Power Automated Controller

b)



c)

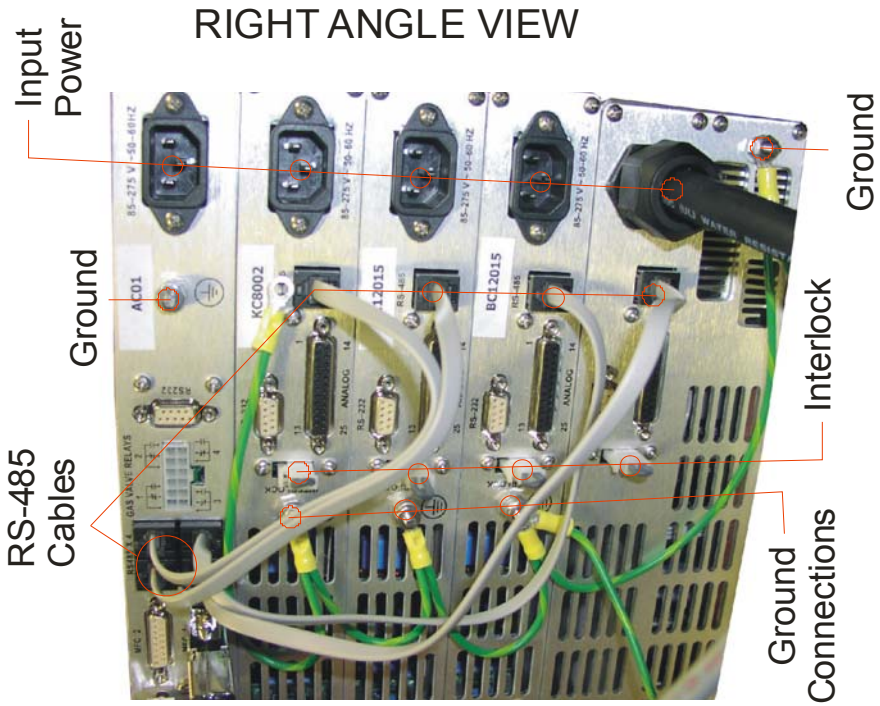


Fig. 3-2 b & c. Rear view of High Power Automated Controller

4. INITIAL OPERATION

This initial operation is done locally from the front panel and serves to both demonstrate and provide familiarization with operation. Make sure that the Auto controller is switched to local mode. When using the gas only mode described below, the Keeper, Bias and Discharge power supplies must also be in the local mode. The description in this section assumes that the installation sequence described in Section 3 of this manual and Section 2 in the ion source manual has been carried out.

4.1 Gas

High-purity gas can be used in the ion source. The hollow cathode requires 99.999%+ pure argon gas for operation. Refer to the Hollow Cathode Electron Source manual or the hollow cathode section of the ion source manual for considerations required for the hollow cathode gas supply. For other process gases, please contact Kaufman & Robinson, Inc. The bottle, regulator and mass flow controller(s) should be installed and gas lines evacuated as described in Section 2.4.3 of the Ion Source manual.

4.2 Power On

Switch on the front panel power switches to the Auto Controller, and the Keeper, two Bias and Discharge power supplies. These switches are the rocker type switches located on the far left of the front panels.

4.3 Operating Mode

There are three selectable operating modes for the Auto Controller. These three modes include Auto Gas, Manual Gas, and Gas Only. All three modes can be selected using the white Operating Mode button on the front panel of the auto controller. Auto Gas and Manual Gas modes are available only when the Auto Controller has established communication with the power supplies.

4.3.1 Auto Gas Mode

When using Auto Gas mode, the gas is automatically adjusted to maintain constant discharge current and voltage once the ion source is running. Check to see if the green Auto Gas LED indicator above the Operating Mode button is on. If it is not, then continue to press and release the Operating Mode button until the green Auto Gas LED is on.

4.3.1.1 Program Select

The Auto controller is shipped with four programs stored. Pressing and releasing the white Program Select button will increment to the next program as indicated by the numbered red LED's on the left side of the Program Select button. The program values will be displayed on the front panels for each program. Program 1 may already be selected when the unit is powered on, if it is not, then press and release the program select button until the red LED for program 1 is on for the initial operation.

The other programs can still be viewed after the Auto Controller is enabled with one of the programs running. **When a program is running and "Program Select" is pressed, the setpoint values of the next program will be displayed for two seconds before switching to that program.** This gives time to review the programs before deciding which one to run. Pressing again within two seconds moves to the next program, etc. Cycling around to the program that's currently running will continue operation without change. Otherwise, the parameters will be ramped to the newly selected program.

4.3.1.2 Gas Setpoints

There are four gas channels. Pressing and releasing the Gas Channel Select button will increment to viewing the gas setpoint in sccm, for the next gas channel for each program. In the Auto Gas mode, the gas is automatically adjusted to maintain constant discharge current and voltage once the ion source is running. The setpoints act as the starting point from which the gas is adjusted. When more than one gas is blended together, a constant ratio of the gas is adjusted based on the initial gas setpoints to maintain the discharge voltage and current for gas channels 1, 2 and 3.

Gas channel 4 is reserved for the Hollow cathode. The setpoint on this MFC is the operating flow for the hollow cathode. Additionally, the gas for the hollow cathode is always flowing at this setpoint value or a preprogrammed minimum flow regardless of the enable/standby selection on the front panel. This is to insure that the minimum gas flow requirement of 15 minutes before starting and after running is met. The Auto Controller can be switched off if it is necessary to turn off the gas flow for other process requirements when operating from the front panel. Note that the Keeper, Bias' and Discharge will all display HLP 7 when the Auto Controller is turned off. This is to indicate that they have lost communication with the Auto controller. These HLP 7 messages will be cleared when the Auto controller is

turned back on. A shut off signal for the hollow cathode gas is also available for remote shut off without turning off the Auto Controller.

During startup of the hollow cathode, the automatic sequencing of the Auto Controller will raise the gas flow to 100 sccm to ignite the hollow cathode in the Auto gas or Manual gas operating modes. After ignition in these two modes, the gas controller will then drop the flow to the operating flow. The recommended operating flow is 10 sccm for up to 10 amps of cathode emission (bias current). One sccm should be added to this flow for each additional ampere of bias current above 10 amps. Operation is possible using less than the recommended minimum, but will reduce the lifetime of the hollow cathode insert. Contact KRI for advice on using less flow for the hollow cathode if necessary.

The gas flow may be adjusted by selecting the gas channel and turning the knob on the front panel of the gas controller before the auto controller is enabled. For the initial operation, leave the gases set at the programmed setpoint(s).

4.3.1.3 Keeper Current Setpoint

The setpoint for the keeper current in amps is shown in the display labeled Keeper Amps on the Keeper Power Supply. Notice that the yellow setpoint LED below the display is on to indicate that the setpoint is being viewed. Once the Auto Controller is enabled, the run value will be displayed and the green run LED will be on.

The keeper current setpoint can be adjusted by turning the Setpoint Adjust knob on the front of the Keeper Power Supply. The keeper current is normally set to 1.5 amps, but will automatically be increased to 2.0 amps to ignite the hollow cathode when the keeper supply is enabled. Once ignited, the keeper current will drop to the setpoint value. Note: If the Bias current is set to less than 0.5 amps, then it may be desirable to increase the keeper current to 2.0 amps to promote longer cathode lifetimes. For the initial operation, leave the keeper current at the 1.5 amp setpoint.

4.3.1.4 Bias Current Setpoint

The set point for the Bias or Emission current in amps is shown in the display labeled Bias Amps on both Bias Power supplies. Note that these currents do not display total Bias current, they are additive. For example; if Bias 1 show 5 amps and Bias 2 show 5 amps, total current is 10 amps. Notice that the yellow setpoint LED below the display is on to indicate that the setpoint is being viewed. Once the

Auto Controller is enabled, the run value will be displayed and the green run LED will be on.

The Bias setpoint can be adjusted by turning the Setpoint Adjust knob on the front of the Bias Power Supplies. This can only be adjusted independently in the standby mode, but is also adjusted automatically when adjusting the Discharge current. This maintains the same Bias to Discharge current ratio. For the initial operation, leave the Bias at the program setpoint. The Auto Controller will select one Bias Supply to be the Master and the other Bias Supply will be the slave. If the setpoint adjustment knob on the front panel is not active, try the other supply.

4.3.1.5 Discharge Parameters

The setpoints for the discharge voltage in volts and the discharge current in amps are displayed on the front panel of the Discharge Power Supply in the displays labeled Discharge Volts and Discharge Amps. Notice that the yellow setpoint LED below the display is on to indicate that the setpoint is being viewed. Once the Auto Controller is enabled, the run values will be displayed and the green run LED will be on.

The discharge voltage and current setpoints can be adjusted using the Setpoint Adjust knob on the front of the discharge controller. These adjustments can be made when the Auto Controller is in Standby or when it is Enabled. The setpoint being adjusted by the knob is indicated by the green LED's on the front panel labeled Amps and Volts. These LED's are located above and below the white Select button on the front panel of the Discharge Power Supply. Pressing and releasing the Select button will switch the parameter being adjusted from Amps (discharge current) to Volts (discharge voltage) or from Volts to Amps. For the initial operation, leave the discharge voltage and current at the program setpoints.

4.3.1.6 Enable

Press and release the white Enable/Standby button on the front panel of the Auto Controller. Notice that the yellow Standby LED under the button turns off and the green Enable LED above the button turns on. The same LED transition from Standby to enable also happens on the Keeper, Bias'/Emission and Discharge Power Supplies as the Auto Controller sequences them on. The gas flow will automatically be adjusted until the program 1 parameters are reached.

Note that the operating range of the ion source may be limited by the vacuum facility pump speed or any other processes that take place while the ion source is running.

4.3.1.7 Standby

Press and release the white Enable/Standby button on the front panel of the Auto Controller. Notice that the yellow Standby LED under the button turns on and the green Enable LED above the button turns off. The same LED transition from Enable to Standby also happens on the three power supplies as the Auto Controller sequences them off.

When the "Learn" feature is turned on, the Auto Controller updates the program and saves a new starting gas flow so the discharge parameters will be reached more quickly the next time the program is run.
Note: The "Learn" feature has been factory set. For directions on how to disable the "Learn" feature, contact KRI.

4.3.1.8 Setpoint Adjustment

When the Auto Controller is in the Auto Gas mode, the ion source parameters can be adjusted before the auto controller is enabled as described above. When the values are adjusted, the program LED will flash to indicate that the program has not been saved. The new values can be acquired by pressing and holding the acquire setpoints button until the program LED stops flashing.

Once the controller is enabled, the discharge voltage and current can be adjusted. Adjusting the discharge current when the auto controller is enabled also adjusts the Bias current. In this case, the Bias current becomes a fixed ratio of the Bias current to discharge current based on the Bias and discharge current setpoints before the Auto Controller was enabled. For example: The discharge current and Bias currents are set respectively to 10.0 amps and 10.4 amps before enabling the auto controller. After enabling, the discharge current is adjusted to 15.0 amps and the Bias current will automatically be adjusted to 15.6 amps. Note the Bias power supply currents are additive so each power supply should indicate 7.8 amps. Press and hold the acquire setpoints button until the program indicator stops flashing to acquire the new setpoints; the old program values will be overwritten with the new values. Once acquired, the program indicator LED will begin flashing again when the acquire setpoints button is released. If adjustments are made and not saved, then the new values will be written to the active program when the Auto Controller

transitions to standby. Pressing the program button once before new values are acquired, or before an enable to standby transition will clear any adjustments and revert back to the original program.

4.3.1.9 Saving a Program

The first step is to select the operating condition. Review the ion source manual to select an operating condition that is within the range of the particular ion source.

Note that the vacuum facility pump speed or other processes that take place while the ion source is running may limit the operating range of the ion source.

A program can be saved when the Auto Controller is enabled or when it is in standby.

When the Auto Controller is in standby, use the program select button to select the program number that will be overwritten. Adjust the setpoints to the desired values as described above and then press and hold the white Acquire Setpoints button on the Auto Controller until the red program LED stops flashing. When this LED stops flashing, the program has been saved.

When the Auto Controller is enabled, first select the program number where the new setpoints will be saved. Next, adjust the setpoints to the desired values and acquire setpoints as described above in section 4.3.1.8 Setpoint Adjustment

Repeatedly pressing and releasing the Select Program button will cycle through the programs. If more than two seconds elapses before the Select program button is pressed and released, the Auto Controller will commit to the program being viewed when it is in the enable state.

4.3.2 Gas Only Mode

When gas only mode is selected, the Auto Controller functions as a gas controller only. Independent control of the each of the four gas channels is possible. The description below outlines the use with one gas channel for the ion source even though similar operation could be obtained using all three gas channels that are available for the ion source. Gas channel 4 is dedicated to the Hollow cathode. Use the Operating Mode Select button to select the gas only mode with the Auto Controller in standby. Selecting the Gas Only mode releases control of the power supplies so

that they can be operated independently. There is no feedback to maintain the discharge parameters. However, at any time during the operation in gas only mode, the setpoints can be acquired for operation later using the Auto Gas mode or the Manual Gas mode.

Note that if there is no communication link to any of the power supplies, the Auto Controller will only function in the gas only mode, which must be selected to clear the HLP 7 message from the display. There will be no communication link if the power is switched off to any of the power supplies or if any RS-485 cable connection on the rear panel is not connected to Auto Controller or either of the power supplies.

There are two modes of operation for the discharge: Constant Current Mode or Constant Voltage Mode. The Constant Current Mode allows for small variations in the discharge voltage while maintaining a constant current and is recommended when operating at 120 V and below. The Constant Voltage Mode will allow for small variations in discharge current and maintains a constant voltage. Constant Voltage Mode is recommended for operation above 120 V.

4.3.2.1 Constant Current Mode

The operating condition selected for this demonstration is with a 10 A, 100 V, discharge, which is Constant Current Mode operation. These conditions are based on an effective vacuum pump speed of 2400 liters per second. Operating parameters for other pump speeds and gases can be found in the Ion Source Manual.

Note that the operating range of the ion source may be limited by the high vacuum pump speed or any other processes that take place while the ion source is running.

- Select Gas 4 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 10 sccm. Gas should be allowed to flow through the hollow cathode for 15 minutes at 10 sccm before proceeding to the next step

- Select Gas 1 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 10 sccm.

- Select Gas 4 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 100 sccm.

- Turn the knob on the Keeper Power Supply until 1.5 amps is indicated in the Keeper Amps display.

- Turn the knob on the Bias Power Supply 1 until 5.4 amps is indicated in the Bias Amps display. Repeat with Bias Power Supply 2. Note that the bias current in amps is usually set equal to or up to 10% greater than the discharge current.

- Use the white Select button on the Discharge Power Supply to select Volts. Turn the knob on the Discharge Power Supply until the discharge voltage is set to maximum as indicated on the Discharge Volts display.

- Use the white Select button on the Discharge Power Supply to select Amps. Turn the knob on the Discharge Power Supply until the discharge current is set to 2.5 amps as indicated on the Discharge Amps display.

- Press the white Enable/Standby button on the Keeper Power Supply. And wait a couple of seconds for the keeper to start the hollow cathode as indicated by the Keeper Amps display reading 1.5 amps.

- Reduce the flow to gas channel 4 to 10 sccm.

- Press the white Enable/Standby button on the Auto Controller.

- Press the white Enable/Standby button on both Bias Power Supplies.

- Press the white Enable/Standby button on the Discharge Power Supply.

- Adjust the gas flow for channel 1 using the Gas Adjust Knob on the Auto Controller until the discharge voltage is approximately 120 V.

- Operate the ion source for at least 10 minutes to clean any contaminates from the ion source that may have been introduced while at atmosphere.

- The discharge voltage will vary slightly during this time. Adjust the gas flow after the 10 minutes to obtain a discharge voltage of approximately 120 V.

- At this point the operating conditions can be saved as a program to be used later in the Auto Gas mode or the Manual Gas mode. To do this, first press the white Program Select Button repeatedly until the desired program number is selected as indicated by the numbered red LED's. Next press and hold the white Acquire Setpoints button for two seconds.

- Stop operation by putting the discharge, bias and keeper power supplies into Standby in that order by pressing the white Enable/Standby button on each.

- Put the gas flow into Standby by pressing the white Enable/Standby button on the auto controller.

4.3.2.2 Constant Voltage Mode

The operating condition selected for this demonstration is with a 10 A, 150 V discharge, which is Constant Voltage Mode operation. The following conditions are based on a vacuum pump speed of 2400 liters per second. Operating parameters for other pump speeds and gases can be found in the Ion Source Manual.

Note that the vacuum facility pump speed or other processes that take place while the ion source is running may limit the operating range of the ion source.

- Select Gas 4 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 10 sccm. Gas should be allowed to flow through the hollow cathode for 15 minutes at 10 sccm before proceeding to the next step

- Select Gas 1 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 10 sccm.

- Select Gas 4 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 100 sccm.

- Turn the knob on the Keeper Power Supply until 1.5 amps is indicated in the Keeper Amps display.

- Turn the knob on the Bias Power Supply 1 until 5.4 amps is indicated in the Bias Amps display. Repeat with Bias Power Supply 2. Note that the Bias current in amps is usually set equal to or up to 10% greater than the discharge current.

- Use the white Select button on the Discharge Power Supply to select Amps. Turn the knob on the Discharge Power Supply until the discharge current is set to maximum as indicated on the Discharge Amps display.

- Use the white Select button on the Discharge Power Supply to select Volts. Turn the knob on the Discharge Power Supply until the discharge voltage is set to 150 volts as indicated on the Discharge Volts display.

- Press the white Enable/Standby button on the Keeper Power Supply. And wait a couple of seconds for the keeper to start the hollow cathode as indicated by the Keeper Amps display reading 1.5 amps.

- Reduce the flow to gas channel 4 to 10 sccm.

- Press the white Enable/Standby button on the Auto Controller.

- Press the white Enable/Standby button on the Bias Power Supplies.

- Press the white Enable/Standby button on the Discharge Power Supply.

- Adjust the gas flow for channel 1 using the Gas Adjust Knob on the Auto Controller until the discharge current is approximately 10 A.

- Operate the ion source for at least 10 minutes to clean any contaminates from the ion source that may have been introduced while at atmosphere.

- The discharge voltage will vary slightly during this time. Adjust the gas flow after the 10 minutes to obtain a discharge current of approximately 10 A.

- At this point the operating conditions can be saved as a program to be used later in the Auto Gas mode or the Manual Gas mode. To do this, first press the white Program Select Button repeatedly until the desired program number is selected as indicated by the numbered red LED's. Next press and hold the white Acquire Setpoints button for two seconds.

- Stop operation by putting the Discharge, Bias and Keeper power supplies into Standby in that order by pressing the white Enable/Standby button on each controller.

- Put the gas flow into Standby by pressing the white Enable/Standby button on the auto controller.

4.3.3 Manual Gas Mode

Manual Gas mode operates the same as the auto gas mode except that there is no feedback loop for the gas flows to maintain the anode parameters. This being the case, the gas channels can all be independently adjusted during operation, where this was not possible in the Auto Gas mode.

The discharge parameters can be set up for either constant voltage mode operation or constant current mode operation as described above for the manual gas operating mode.

Constant voltage mode is typically used for discharge voltages of 120 volts or more. The discharge current is usually set to maximum, while the operating voltage is set to the desired value on the front panel. The gas flow to the ion source is then adjusted to control the ion source current.

Constant current mode is typically used for discharge voltages less than 120 volts. The discharge voltage is usually set to maximum, while the operating current is set to the desired value on the front panel. The gas flow to the ion source is then adjusted to control the ion source voltage.

Select the Manual Gas mode using the Operating Mode button. Select the program to run using the Program Select button. Enable the program by pressing the Enable/Standby button on the Auto Controller. Press the Enable/Standby button again to stop the program and put the units into Standby.

Saving a program is the accomplished in the same manner as described above for the Auto Gas and Gas Only operating modes.

5. GENERAL OPERATION

The quickest way to start operation of the KRI Ion Source and its Controller is to follow the sequence described in Section 4, Initial Operation. This section gives a general overview of the ion source power supplies and there interconnection with the ion source.

5.1 Description of Ion-Source/Controller Components

The operation of the End Hall Ion Source with its power supplies can be generally understood by reference to the schematic block diagram of Fig. 5-1.

The commonly used symbols for the currents and voltages are also shown in Fig. 5-1. The voltage and current of the Keeper Power Supply are V_k, and I_k; the voltage and current of both Bias Power Supply are V_b, and I_b; while the voltage and current of the Discharge Power Supply are V_d, and I_d. The discharge voltage and current has sometimes been referred to as the anode voltage and current and given as I_a and V_a, but only the symbols I_d and V_d will be used herein.

A mass flow controller (MFC) establishes a gas flow through the hollow cathode of 100 sccm to establish a high enough pressure that a Paschen discharge can be established when the keeper voltage, V_k, of 800 volts is applied. The Paschen discharge heats the hollow cathode until surfaces inside the cathode tube are hot enough for thermionic emission. Once the thermionic emission is established, only about 10 – 40 volts are required to keep the hollow cathode ignited using 1.5 amps of keeper current, I_k. After ignition, the gas flow to the hollow cathode is reduced to the operating flow, typically 10 sccm.

After the hollow cathode is ignited, a negative bias voltage, V_b, is applied to the cathode to establish the electron emission. The bias current, I_b, is the amount of electron current in amps that is available to operate the ion source.

With the bias current initialized, the other MFC supplies gas to the ion source. The neutral gas molecules flow into anode. The Discharge Power Supply applies a positive potential, V_d, to the anode. Some of the electrons from the hollow cathode are attracted to the positive anode, but they are impeded by a magnetic field (not shown in the figure). This magnetic field confines the electrons until they bump into neutral gas atoms and knock off electrons, creating positive ions in the process. The ions are repelled from the positive anode and flow outward. Some of the electrons from the hollow cathode mix

with the outward flowing ions to equalize the charge. This mixture of ions and electrons is the neutralized ion beam, although it is usually referred to as the ion beam or plasma beam.

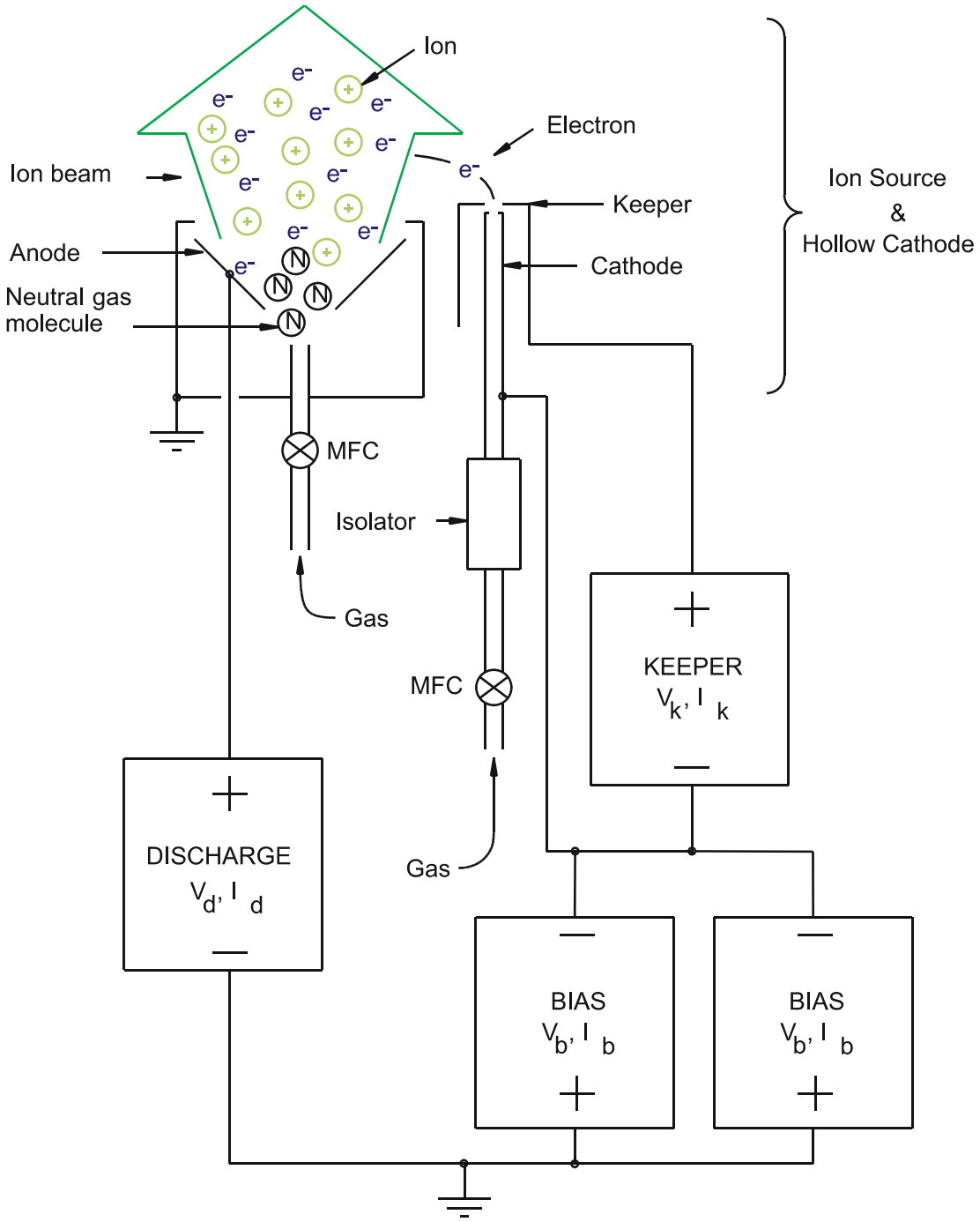


Fig. 5-1. Schematic block diagram of ion source and power supplies.

6. REMOTE/AUTOMATED CONTROL

The Auto controller has a variety of remote control options available. These options include a female DB-25 interface, A female DB-37 analog/digital interface and a female DB-9 RS-232 serial interface. Note: The Auto Controller must be in Standby to switch between local and remote operating modes.

6.1 Remote Control using the DB-25 Connector

The DB25 pin-out has been designed to be "drop in" compatible with the Commonwealth Scientific Mark I/Mark II Filament version power supplies, minimizing the impact to a modern power supply design. With the hollow cathode version, only the remote enable pins 7 and 20 are active. When using the remote enable, the programs are entered and stored using the front panel as described in Operation sections 4 and 5 of this manual. After the programs have been acquired using the front panel, switch the front panel from local to remote. Connect pin 7 (Beam on) to pin 20 (Beam on return) on the rear panel DB-25 connector to enable the program selected from the front panel.

6.2 Remote Control using the DB-37 Connector

The DB-37 connector is an extended control set which gives the operator full access to the Auto Controller inputs and outputs. There are two main options when using the DB-37 connector for remote control of the Auto Controller. One option is to enable one of the four programs stored in the auto controller. These programs can be acquired using the front panel as described in the operation sections 4 and 5 of this manual. The other option is to input the desired operating parameters and then use the Auto Controller for sequencing and/or automatic feedback to keep the discharge parameters constant. **If the DB-37 connector is to be used as a remote interface, then pin 18 (DB-37 Select) must be connected to common pin 7 or 8 on the DB-37 for all the options described below.**

6.2.1 Remote Enable of the Four Stored Programs using the DB-37 Connector

The DB-37 I/O allows program selection through the rear input ports. When using remote enable, the programs can be acquired using the front panel as described in Operation sections 4 and 5 of this manual.

Pins 16 (Program select 0) and pin 34 (Program select 1) on the rear panel DB-37

connector are used to select the four programs. Making connections to common pin 7 or leaving the connections open as indicated below in table 6-1 selects the programs. Once the program is selected, connecting remote enable pin 36 to common pin 7 or 8 on rear panel DB-37 connector enables it. Removing the connection between pin 36 and pin 7 or 8 returns the Auto Controller to Standby. Switching to another program while the Auto Controller is enabled will instantly commit to running the program that has been selected.

Table 6-1. Remote program selection using pins 16 and 34 on the DB-37.

Program Number	Pin 34	Pin 16
1	Open	Open
2	Open	Common
3	Common	Open
4	Common	Common

6.2.2 Remote Gas Channel Setpoint Description for the DB-37 Connector

The gas channel setpoints all use 0-5 volt inputs (referenced to pin 13) that correspond with 0 to the maximum output for the MFC in sccm. A setpoint of zero also de-energizes the gas relay on the rear panel and sends the valve off command to the mass flow controller. The gas relays are also de-energized and the valve off commands are sent to the mass flow controllers when the Auto Controller is in standby. This is true except for gas channel 4, which is dedicated to the hollow cathode. The hollow cathode gas will flow at a preprogrammed minimum flow if a setpoint value less than this minimum is programmed. The preprogrammed minimum is typically between 5 and 10 sccm. If necessary, this minimum can be field programmed to another value; contact KRI for instructions. This gas flow can be disabled for other process considerations by connecting pin 15 (gas CH4/HC off) to one of the common pins 7 or 8 on the DB-37 connector. However, the hollow cathode gas should be allowed to flow for 15 minutes before and after operating the hollow cathode. Turning the gas flow off momentarily during this 15 minute time period is acceptable. It is often desirable to turn off the gas momentarily to achieve a minimum base pressure in the vacuum chamber before starting a process.

The gas channel setpoints function differently depending on the operating mode selected. The Auto Gas, Manual Gas and Gas Only modes are selected from the front panel. The functions of the gas setpoints are described below for these three operating modes.

- **Remote Gas Channel Setpoints using Auto Gas Mode**

  The remote gas setpoints are not available when using the auto gas mode, instead the starting gas flows are established by programming them from the front panel for each program. The gas for channel 4 is reserved for the hollow cathode. This gas flows continuously at the front panel set point value regardless of the enable/standby selection. For processes that require a minimum vacuum base pressure, this gas flow can be disabled by connecting pin 15 (gas CH4 off) to common pins 7 or 8. See the Hollow Cathode Electron source manual for the gas flow requirements before and after the hollow cathode is started.

- **Remote Gas Channel Setpoint using Manual Gas Mode**

  The remote gas setpoints are active when using the manual gas mode. The pins for these setpoints are listed below in table 6-2. The gas for channel 4 is reserved for the hollow cathode. This gas flows continuously at set point value or a preprogrammed minimum regardless of the enable/standby selection. The preprogrammed minimum is typically between 5 and 10 sccm. For processes that require a minimum vacuum base pressure, this gas flow can be disabled by connecting pin 15 (gas CH4 off) to common pins 7 or 8. See the Hollow Cathode Electron source manual or the hollow cathode section of the ion sources manual for the gas flow requirements before and after the hollow cathode is started.

- **Remote Gas Channel Setpoints Using the Gas Only Mode**

  When the Gas Only mode is selected from the front panel, the Auto Controller continuously responds to the applied gas setpoints once the Auto Controller is enabled.

6.2.3 Remote Analog Setpoint Option on the DB-37 Connector

The remote analog setpoint option allows active control over the setpoints while the Auto Controller is enabled in the auto gas mode. The four stored programs are not available with the remote analog setpoint option.

Switch the front panel from local to remote and also connect Remote setpoint pin 17 to common pin 7 or 8 on the DB-37. This selects the remote setpoint options for both the DB-25 and the DB-37 ports. The remote analog set points are applied to the analog pins described below in Table 6-2. To enable the system, connect the remote enable pin 36 to common pin 7 or 8 on the rear panel DB-37 connector.

The starting gas setpoints are taken from the front panel when operating in Auto Gas mode. The Auto Controller then automatically adjusts the gas to maintain the program values for the discharge voltage and current, while maintaining the ratio established by the starting gas setpoints.

Table 6-2. Pin descriptions for the analog inputs on the DB-37 connector.

Pin Number	Description
3	Discharge Voltage Setpoint. 0-5 volts correspond with 0 to the maximum output voltage for the Discharge Power Supply. Referenced to pin 7 or 8.
4	Bias current setpoint. 0-5 volts correspond with 0 to the maximum Bias current in amps for the Bias Power Supply being used. Referenced to pin 7 or 8.
7	Common.
8	Common.
11	Gas Channel 1 Setpoint. Referenced to pin 13.
12	Gas Channel 3 Setpoint. Referenced to pin 13.
13	Gas Setpoint Common. Reference for gas channel setpoints. See section 6.2.3.1 below.
22	Discharge Current Setpoint. 0-5 volts correspond with 0 to the maximum level of discharge current in amps for the Discharge Power Supply that is being used. Referenced to pin 7 or 8.
26	Keeper Current Setpoint. 0-5 volts corresponds with 0 – 2 amps. This should usually be set to 1.5 amps
30	Gas Channel 2 Setpoint. Referenced to pin 13.
31	Gas Channel 4 Setpoint. Referenced to pin 13.

6.2.4 Analog Outputs for the DB-37 Connector

The analog outputs for monitoring the operating parameters are available on the DB-37 connector as described below in table 6-3. The analog outputs are available in both remote and local operating modes.

When the controller is in Standby Mode, the values on the analog output pins are the setpoint values stored in the individual programs. The setpoints for each of the four programs can be reviewed in standby mode by selecting the program as indicated in table 6-1 above. Note that the setpoints can only be viewed with the Auto Controller in standby. Once a program is enabled, the values for the analog outputs are the actual values.

Table 6-3. Pin descriptions for analog outputs on the DB-37 connector.

Pin number	Description
1	Bias Current Output. 0-5 volts correspond with 0 to the maximum Bias current in amps for the Bias Power Supply being used. Referenced to pin 7 or 8.
6	Bias Voltage Output. 0-5 volts correspond with 0 to the maximum output voltage for the Bias Power Supply. Referenced to pin 7 or 8.
7	Common.
8	Common.
9	Channel 1 Gas Flow Output. 0-5 volts correspond with 0 to the maximum output in sccm for the channel 1 MFC. Referenced to pin 27.
10	Channel 3 Gas Flow Output. 0-5 volt corresponds with 0 to the maximum output in sccm for the channel 3 MFC. Referenced to pin 27.
20	Discharge Current Output. 0-5 volts correspond with 0 to the maximum level of discharge current in amps for the Discharge Power Supply that is being used.
21	Discharge Voltage Output. 0-5 volts correspond with 0 to the maximum level of discharge voltage in volts for the Discharge Power Supply that is being used.
25	Keeper voltage output. 0-5 volts correspond with 0-800 volts. Referenced to common pin 7 or 8.
27	Gas flow Output common.
28	Channel 2 Gas Flow Output. 0-5 volts correspond with 0 to the maximum output in sccm for the channel 2 MFC. Referenced to pin 27.
29	Channel 4 Gas Flow Output. 0-5 volts correspond with 0 to the maximum output in sccm for the channel 4 MFC. Referenced to pin 27.
37	Keeper current output. 0-5 volts correspond with 0-2 amps. Referenced to common pin 7 or 8.

6.2.5 Run Fault and Beam Good on the DB-37 Connector

The Run Fault and Beam Good are available for additional monitoring of the operational state of the auto controller and associated power supplies. These pins are described below in table 6-4.

A Run Fault occurs when the discharge fails to start or goes out. It also occurs if the operating parameters are out of range for more than 30 seconds.

In order for these operating parameters to be in range:
1. The gas flow must be within 50% of the setpoint.
2. The Discharge current must be within ± 1.28 amps of the setpoint.
3. The Discharge voltage must be within ± 12.8 volts of the setpoint.
4. The Bias current must be within 75% of the discharge current.

When a run fault occurs, the Auto Controller reverts to Standby and a help code or error message is displayed on the front panel of the Auto Controller. Use the help codes and error messages defined in Diagnostics section 7 of this manual to determine the cause of the Run Fault. The help code or error message is cleared when the remote enable pin 36 is released from common pin 7 or 8.

The Beam Good function gives a real time check of the operating parameters. If the operating parameters are in range, the two Beam Good pins are shorted together. If the operating parameters are out of range, then the beam good pins are open. The Beam Good function uses the same range for operating parameters as described above for the Run Fault.

Table 6-4. Run Fault and Beam Good pin descriptions.

Pin Number	Description
7	Common.
8	Common
23	Beam Good 1. Shorted to pin 24 when the operating parameters are in range.
24	Beam Good 2. Shorted to pin 23 when the operating parameters are in range.
19	Run Fault. Outputs 5 volts when a run fault occurs, otherwise it outputs 0 volts. Referenced to common pins 7 or 8.

6.2.6 Description of the DB-37 pins

The DB-37 pin analog/digital interface has been described above by sorting out the various remote operating options. Table 6-5 below is provided as a reference with a description of all the pins. The descriptions provided below are brief; see the detailed descriptions above to understand the full functionality.

Table 6-5. Pin descriptions for the female DB-37 connector on the Auto Controller.

Pin Number	Description
1	Bias Current Output. 0-5 volts correspond with 0 to the maximum Bias current in amps for the Bias Power Supply being used. Referenced to pin 7 or 8.
2	No Contact
3	Discharge Voltage Setpoint. 0-5 volts correspond with 0 to the maximum output voltage for the Discharge Power Supply. Referenced to pin 7 or 8.
4	Bias current set point. 0-5 volts correspond with 0 to the maximum Bias current in amps for the Bias Power Supply being used. Referenced to pin 7 or 8.
5	Auxiliary + 12 volts. Referenced to pin 7 or 8.
6	Bias Voltage Output. 0-5 volts correspond with 0 to the maximum output voltage for the Bias Power Supply. Referenced to pin 7 or 8.
7	Common.
8	Common.
9	Channel 1 Gas Flow Output. 0-5 volts correspond with 0 to the maximum output in sccm for the channel 1 MFC. Referenced to pin 27.
10	Channel 3 Gas Flow Output. 0-5 volt corresponds with 0 to the maximum output in sccm for the channel 3 MFC. Referenced to pin 27.
11	Channel 1 Gas Setpoint. 0-5 volts correspond with 0 to the maximum output for the MFC connected to Channel 1. Referenced to pin 13.
12	Channel 3 Gas Setpoint. 0-5 volts correspond with 0 to the maximum output for the MFC connected to Channel 3. Referenced to pin 13.
13	Gas Setpoint Common.
14	Gas Channel 3 shut off. Connecting this pin to common pin 7 or 8 will disable the gas flow to the MFC and deactivate the additional MFC relay for channel 3, regardless of the input flow setting.

Pin Number	Description
15	Gas Channel 4 shut off. Connecting this pin to common pin 7 or 8 will disable the gas flow to the MFC and deactivate the additional MFC relay for channel 4, regardless of the input flow setting.
16	Program Select 0. This pin is the 0 bit for selecting programs 1 through 4 using negative logic levels of 0 and 5 volts
17	Remote Setpoint Select. When this pin is connected to common pin 7 or 8, the remote setpoints are enabled and the four programs are not used.
18	DB-37 control select. The pin is connected to common pin 7 or 8 to enable the DB-37 connector. When the connection is left open, the DB-25 is active.
19	Run Fault. When the Auto Controller is enabled, this pin will indicate a run fault if it is at a high logic level of 5 volts. If there is no run fault, then this pin will be at a low logic level of 0 volts.
20	Discharge Current Output. 0-5 volts corresponds with 0 to the maximum level of discharge current in amps for the Discharge Power Supply that is being used.
21	Discharge Voltage Output. 0-5 volts corresponds with 0 to the maximum level of discharge voltage in volts for the Discharge Power Supply that is being used.
22	Discharge Current Setpoint. 0-5 volts corresponds with 0 to the maximum level of discharge current in amps for the Discharge Power Supply that is being used.
23	Beam Good 1. Shorted to pin 24 when the operating parameters are in range.
24	Beam Good 2. Shorted to pin 23 when the operating parameters are in range.
25	Keeper voltage output. 0-5 volts corresponds with 0-800 volts. Referenced to common pin 7 or 8.
26	Keeper Current Setpoint. 0-5 volts corresponds with 0 – 2 amps. This should usually be set to 1.5 amps
27	Gas flow Output common. Return for gas flow output pins 8, 9, 28 and 29.
28	Channel 2 gas flow Output. 0-5 volt corresponds with 0 to the maximum output in sccm for the channel 2 MFC. Referenced to pin 27.
29	Channel 4 gas flow Output. 0-5 volt corresponds with 0 to the maximum output in sccm for the channel 4 MFC. Referenced to pin 27.

Pin Number	Description
30	Channel 2 setpoint. 0-5 volts corresponds with 0 to the maximum output for the MFC connected to Channel 2. Referenced to pin 13.
31	Channel 4 setpoint. 0-5 volts corresponds with 0 to the maximum output for the MFC connected to Channel 4. Referenced to pin 13.
32	Gas Channel 1 shut off. Connecting this pin to common pin 7 or 8 will disable the gas flow to the MFC and deactivate the additional MFC relay for channel 1, regardless of the input flow setting.
33	Gas Channel 2 shut off. Connecting this pin to common pin 7 or 8 will disable the gas flow to the MFC and deactivate the additional MFC relay for channel 2, regardless of the input flow setting.
34	Program Select 1. This pin is the 1 bit for selecting programs 1 through 4 using negative logic levels of 0 and 5 volts
35	No Contact.
36	DB-37 Remote Enable. Enables the auto controller if control select pin 18 is connected to common pin 7 or 8.
37	No Contact.

6.3 Interlock

A two-pin interlock is located on the rear panel. The interlock pins must be shorted to allow operation of the Auto Controller. When the interlock pins are open, the Auto Controller remains in standby and the Auto Controller displays ”Int Loc.” The red Open Interlock indicators on the front panels of the power supplies are also lit when the Auto Controller interlock is open if there is an RS-485 communication link. The interlock pin descriptions are given below in table 6-6.

Note that the interlock for the Auto Controller does not open the interlocks for the Keeper, Bias and Discharge power supplies when the Auto controller is in the Gas Only mode or when it is turned off. In these cases, the power supplies function as independent units. These power supplies each have interlocks that prevent operation if the two interlock pins are not closed. The pin descriptions are the same as the interlock for the Auto Controller. **The five interlocks for the Auto Controller, Keeper Power Supply, Bias Power Supplies and Discharge Power Supply must all be used to prevent operation for all contingencies.**

Table 6-6. Interlock connections for the Auto Controller, Keeper Power Supply, Bias Power Supply and Discharge Power Supply.

Pin Number	Description
1	Active Low Interlock – Connect to common (Interlock pin 2, or DB-37 pin 7 or 8) to enable.
2	Interlock Return – Common

6.4 Remote Control using the RS-232 Serial Interface

The RS-232 serial interface provides full remote control of the Auto Controller. The Remote/Local select on the front panel must be used to set the unit to remote to enable the remote control.

6.4.1 Interface cable

The interface cable for the Auto controller must be a straight through type and must have a male DB-9 connector to connect to the female connector on the rear panel of the Auto Controller.

6.4.2 Communication settings

The baud rate is 9600 b/s with 8 data bits, one stop bit and no parity. The baud rate can be changed if desired. See the Auto controller setup document in the appendix if another baud rate is required.

6.4.3 Communication overview

The acceptable command/response behavior for the Auto-Controller is described below. The action/reaction of the Auto-Controller to commands may be dependent on several factors or conditions, such as configuration and current system states. These dependencies are outlined below for each command/response category.

6.4.4 Commands, queries and responses.

The auto controller can be configured to use two types of cathode/neutralizers. The configuration described in this manual includes only those commands that are used with the Hollow Cathode. Contact KRI for instructions on configuring the auto controller for a cathode/neutralizer other than hollow cathode.

The following convections are used for the command and query descriptions in the following subsections:

“ “ – Text or numerical values inside double quotation marks indicate the exact response from the Auto Controller. The quotation marks are not included in the actual response.

‘ ‘ – Text inside single quotation marks indicates a state or mode for the auto controller.

< > – Text inside arrow head brackets indicates parameters that are included with a command or command string. The brackets are not included when issuing the command.

( ) – Parentheses surround a numerical value or set point included in the command. The parentheses are not included when issuing the command.

All commands are upper-case sensitive. Lower-case commands and queries will be interpreted as invalid commands.

Any command or query that requires a response must be terminated, at the minimum, with a Carriage Return (CR) character. (ASCII 13 or Hex 0x0D). However, the exact response is determined by whether ‘Terse’ or ‘Verbose’ mode is active, as described below in the Verbose Command section. All commands are expected to be terminated with a CR/LF indicated by <cr><lf> in the description below.

6.4.4.1 VRB - Verbose Command

The VRB command sets a flag for more descriptive responses to commands and queries.

The default power-up state of the unit is ‘Terse’ mode. In this mode, the response to a command is strictly limited to a carriage return (CR) (ASCII 13 or Hex 0x0D). The response to a query will also include values or parameters as a response, but with no descriptive text. Invalid commands or syntactical errors are ignored.

Once the VRB command is issued, the unit will remain in ‘Verbose’ mode, until it is reset to ‘Terse’ by a power down/power up sequence or the *RST command is issued. In the ‘Verbose’ mode, the response to a

valid command or query is “OK” followed by CR/LF and the “>” symbol as the next line prompt for the following command/query. The response to a query will also include the requested information with descriptive test. Invalid commands generate an “Invalid Command” response followed by CR/LF and the “>” as the next line prompt.

Command: VRB

Example: VRB<cr><lf>

Response: “OK”

The RS-232 remote must be ‘Enabled’ as described in the next section before the issuing the VRB command.

6.4.4.2 COM - Enable RS-232 Command or Status Query

The COM command will enable, disable or query the status of RS232 remote control of the auto controller depending on the parameter following it.

The default power-up state is ‘Disabled’. In order to ‘Enable’ the RS232 remote control, ‘Remote” must be selected using the front panel Local/ Remote button. Once ‘Enabled’, the RS-232 remote control locks out all front panel controls, except for the ON/OFF switch and Gas Select. The Gas Select button is left active to allow monitoring of individual gas flow channels. Once the RS-232 is ‘Enabled’ the unit must be in ‘Standby’ in order to return control to the front panel ‘Local’ or rear analog ‘Remote’.

The state of the system can be controlled or queried based on the format of the command. If the ? character is included in the command, the present state of RS-232 remote control will be returned.

Command: COM:<parameter> - ‘Enable’ or ‘Disable’ RS-232 remote.

Command: COM? – Get the RS-232 remote control state.

Parameter/Response:

1 = Enabled
0 = Disabled
? = Return current state.

COM:1 – Place unit in 'RS-232 Remote' control.

If the unit is not in front panel remote and standby, the unit issues the following response:

"Unit must be in STANDBY AND front panel REMOTE".

COM:0 – Disable 'RS232 remote' control.

If the unit is not in 'Standby' when this command is issued, if not the unit responds with:

"Unit must be in STANDBY".

COM? – Query of remote control state.

.

If the unit is in 'Verbose', the response is "Enabled" or "Disabled".

If the unit is in 'Terse', the response is "1", or "0".

Example: COM:0<cr><lf> – Disable RS-232 remote control.

Example: COM:1<cr><lf> – Enable RS232 remote control.

Example: COM? <cr><lf> – Get present output state.

If COM is not 'Enabled', then the response to commands will be "Comm Inactive" in both 'Terse' and 'Verbose' modes. The unit will respond to query's regardless of the COM state.

6.4.4.3 *IDN? - Unit Identification Query

The *IDN? command will return a unit identification string. The form of this command follows the SCPI standard query form.

Command: *IDN?

Response:

The KRI Auto-Controller will return information in the following form: <Manufacturer>,<Model>,<Front panel firmware version>, <Main board firmware version>,<FPGA firmware version>. The form of the

firmware version number is month/day/year (MMDDYY).

Example: *IDN?<cr><lf>

Example response: “KRI,AC1,102862,052690,111506”

6.4.4.4 *RST – Reset Command

The RST command will return to the unit to ‘Standby’ and clear any ‘recoverable’ error message(s). The unit will also be set to ‘Terse’ mode

Command: *RST

Example: *RST<cr><lf>

Note: The only ‘recoverable’ errors are:

HLP 10 – Start Failure
HLP 11– Run Fault
HLP 12– Gas Fault

6.4.4.5 *TST? – Self Test Query

The *TST? command performs a unit self test and report results.

A non-zero return value will correspond to the associated front panel error message as outlined below. If more than one error is active during the query, a string of all active HLP xx numbers will be displayed, where xx are numbers. The response will be the same in ‘Terse’ or ‘Verbose’ mode.

Command: *TST?

Example: *TST?<cr><lf>

Error message definitions:

0 = No error. Unit functioning normally.
4 = HLP 4 – Unit not ready.
7 = HLP 7 – Open interlock.
9 = HLP 9 – Invalid configuration.
10 = HLP 10 – Start fault.
11 = HLP 11 – Run fault.

12 = HLP 12 – Gas fault.
13 = HLP 13 – Internal communication error.

Example Response: “10”

6.4.4.6 OUT - System Level Output Control Command or Status Query

The OUT command ‘Enables’, ‘Disables’, or queries the output state of the system depending on the parameter following it.

Command: OUT:<parameter> – To set the output state.
Command: OUT? – To get the output state.

Parameter/Response:

0 = Standby.
1 = Enabled.
? = return current state.

Example: OUT:0<cr><lf> - Put the unit in ‘Standby’.

Example: OUT:1<cr><lf> - ‘Enable’ the unit.

Example: OUT? <cr><lf> – Get present state of output.

If the unit is in ‘Verbose’, the response will be “Standby” or “Enabled”,

If the unit is in ‘Terse’, the response will be “0”, or “1”.

If the RS-232 is not enabled, the unit will respond with “Comm Inactive”.

6.4.4.7 MDE - Mode Set Command or Mode Query

The MDE command sets or queries the Operating Mode of the system when the unit in ‘standby’ and the COM is ‘enabled’. The state of the Operating Mode can be queried at any time. In the case of a mode set command it takes a parameter indicated below. If it is a mode query, then it returns the same form as the parameter indicating the current mode.

Command: MDE:<parameter>
Command: MDE?

Parameter/Response:

0 = Auto Gas.
1 = Manual Gas.
2 = Gas Only.

Example: MDE:0<cr><lf> - Put unit in 'Auto Gas'

If COM is active and unit is 'Enabled', the response of the unit is: "Unit must be in STANDBY".

If the COM is not 'Enabled', the command is ignored both in 'Terse' and 'Verbose'.

Example: MDE?<cr><lf> - Returns present mode.

If the unit is in 'Verbose', the response is "Auto Gas", "Manual Gas", or "Gas Only".

If the unit is in 'Terse', the response is "0", "1", or "2".

6.4.4.8 BEAM - Beam Good Query

The BEAM query Indicates if a stable operating point has been achieved.

Command: BEAM?

Response is "1" if beam good, "0" if beam not good. This response is for both 'Terse' and 'Verbose' mode.

Criteria for Beam Good:

Discharge Current within ± 1.28 A.

Discharge Voltage within ± 12.8 V.

Gas Flow at least 50% of setpoint.

Emission current at least 75% of setpoint.

6.4.4.9 P - Program Value Read/Write Command

The P command selects or queries the active program, or sets or queries the active operating values for a program depending on the parameters included with the command. The operating values are the gas flows for the MFC's, and the currents and voltages for the power supplies. The P command can be used to set or query the values for individual parameters or for a string of parameters depending on the format of the command.

The general form of the program read/write command is:

Command: P<program#>:<parameter> (value)

The <parameter> and (value) fields are optional. The command can be turned into a query by substituting ? for the <program#>, <parameter>, and (value) fields. The interpretation of the query is dependent on where the ? appears as outlined below.

- **Set or query the active program number**

P<program#><cr><lf> - Set active program to <program#>

P<?><cr><lf> - Get active program number.

Acceptable program numbers would be 1 to 4.

Any parameters following the ? character for this command will be ignored.

Any parameters following <program#> without the <:> as a delimiting character before the <parameter> field will be ignored.

Example: P4<cr><lf> - Set active program number to 4

Example: P?<cr><lf> - Get active program number

- **Set or query the values for individual program parameters.**

P<program#>:<parameter> (value) – Set specific <program#> <parameter> to (value)

P<program#>:<parameter> (?) – Get specific <program#> <parameter> (value)

There are 9 <parameters> for setting an individual (value). Each of these <parmeters>, which are three letters long, are listed below along with the description and the number of significant digits and decimal places shown as x:

1. GS1 – Gas Channel 1, xxx.x
2. GS2 – Gas Channel 2, xxx.x
3. GS3 – Gas Channel 3, xxx.x
4. GS4 – Gas Channel 4, xxx.x
5. DSV – Discharge Voltage Target, xxx.xxx
6. DSI – Discharge Current Target, xx.xxx
7. BEI – Emission/Bias Current Target, xx.xxx
8. BSV – Emission Voltage Target, xxx.xxx
9. KPI – Keeper Current Target, x.xxx

The (values) for each <parameter> may have decimal points and decimal places included or omitted if there are no significant digits beyond the decimal point. However, if the first significant digit falls after a decimal point, then a zero must precede the decimal point or an “Invalid Command” response will be generated. Decimal places beyond the anticipated place will be truncated.

Example: P4:GS1 10<cr><lf> - Set program 4 channel 1 gas flow to 10 sccm.

Example: P1:DSV?<cr><lf> - Get program 1 Discharge voltage value.

Example response in ‘Terse’ or Verbose mode: “200.000”

- **Set or query the values for ALL program parameters**

The parameter <ALL> can be used to set or get all program parameter values. The order of the parameters is the same as the order shown above, as are the significant digits and the decimal point criteria.

P<program#>:ALL (value),(value),(value)….<cr><lf> – Set ALL program parameters to value list.

P<program#>:ALL?<cr><lf> - Get all the program values.

NOTE!! In the following examples, the comma-delimited strings are

shown with their mnemonic equivalents listed above. In real use, these abbreviations would be actual numerical values. These numerical values must be valid for the configuration being programmed remotely since the Auto-Controller does not know the maximum ranges of the units attached. The target values returned include the Gas Channels, Discharge voltage and current, Emission/Bias voltage and current, and the Keeper voltage and current.

In using the ALL parameter to set targets, the list of values must be comma delimited and appear in the order shown. Any value that is to remain unchanged can be omitted, but the comma delimiter between parameters must be included in the input string. In the second example, DSI and BSV remain unchanged in the target program.

Example: P1:ALL GS1, GS2, GS3, GS4, DSV, DSI, BEI, BSV, KPI<cr><lf>

Example: P1:ALL GS1, GS2, GS3, GS4, ,DSV,, BEI,, KPI<cr><lf>

When using the ALL command in 'Terse' mode to get all the program values, they will be returned as a comma delimited string of values in the same order as those shown above. The decimal points and the number of decimal places are shown in the example below.

Example: P1:ALL?<cr><lf>

Example Response:

"10.000, 0.000, 0.000, 10.000, 200.000, 3.000, 3.000, 120.000, 1.500".

When using the ALL command in 'Verbose' mode, a list including the name of the value, and the actual numerical value will be returned. A line feed <lf> will separate the returned values.

Example: P1:ALL?<cr><lf>

Example response:

"Gas Channel 1 = 10.000
Gas Channel 2 = 0.000
Gas Channel 3 = 0.000

Gas Channel 4 = 10.000
Discharge Volts = .200.000
Discharge Amps = 3.000
Emission/Bias Amps = 3.000
Bias Volts = 120.000
Keeper Amps = 1.500".

The command can also be used to set or get a single value for a program.

Example: P1:DSV 200 – Set the Discharge voltage for program 1 to 200 volts.

If the auto controller is in the 'Auto Gas' mode, then the setpoint current (DSI) will be the setpoint Discharge current. The gas flow will be the starting flow. Once enabled, the gas flow will be automatically adjusted to maintain the discharge current.

If the auto controller is in the "Manual Gas' mode; either the Discharge current (DSI) or Discharge voltage (DSV) should be set to maximum, while the other is set to the desired operating value. The gas flow determines the discharge parameter that has been set to maximum.

If the Auto Controller is in the 'Gas Only' mode, all the setpoints and queries will still be valid, but only the gas will be enabled when issuing the OUT:1 command. Issuing the OUT:0 command will disable the gas. In using the ALL parameter to set targets, the list of values must be comma delimited and appear in the order shown below. Any value that is to remain unchanged can be omitted, but the comma delimiter between parameters must be included in the input string. In the second example, GS2 remains unchanged in the target program. In 'Gas Only' mode, the supply targets are still active, so that a series of eight comma delimiters will need to follow the command if the ALL parameter is used.

Example: P1:ALL GS1, GS2, GS3, GS4, , , , , <cr><lf>

Example: P1:ALL GS1, , GS3, GS4, , , , ,<cr><lf>

The Auto Controller does not know what (values) are acceptable for the power supply <parameters>. If (values) larger than the output for the power supplies are programmed, the auto controller will set

those (values) to the maximum value. However, this is not true for the gas channel values. If a gas channel (value) is larger than the defined maximum, the auto controller will respond with:

"Target value greater than defined max".

If a gas channel maximum is set to 0 or off, then sending a (value) to that gas channel will generate the following response:

"Gas Channel x disabled" where x is the gas channel number.

It is very important to understand the operating limits of the Ion Source and Hollow Cathode to prevent damage. Review the ion source and hollow cathode manuals to determine appropriate operating conditions. Contact KRI for assistance in establishing operating conditions if necessary.

6.4.4.10 R - Monitor Command for Reading the Actual Feedback Values

The R command is used to get the actual feedback values from the auto controller. It uses the same parameters as those described above for the P command, except that there is no program number required and the ? character is not used.

R:<parameter> – Get the current running (value) of <parameter>

Values are reported in Amps, Volts or sccm, appropriate for the selected parameter(s).

Example: R:GS2<cr><lf> – Get current value of Gas Channel 2 feedback.

Example: R:ALL<cr><lf>

Example response in 'Verbose' mode:

"Gas Channel 1 = 18.300
Gas Channel 2 = 0.000
Gas Channel 3 = 0.000
Gas Channel 4 = 10.000
Discharge Volts = 200
Discharge Amps = 3.000
Keeper Volts = 31.400

Keeper Amps = 1.500
Bias Volts = 38.000
Bias Amps = 3.000”
In ‘Terse’ mode the response will be a comma delimited string of values only in the same as order shown above for the ‘Verbose’ mode.

6.4.4.11 CFG? – Query current system configuration

The CFG? Command is a query of what the Auto-Controller thinks the current configuration is based on the initial setup.

Command: CFG?

In VERBOSE, the responses are:
“Filament”
“Hollow Cathode with BV”
“Hollow Cathode without BV”
“Gas Only”
“Unknown”

In ‘TERSE’, the responses are: “0”, “1”, “2”, “3” or “4”, respectively.

6.4.4.12 LRN – Learn Command or Learn Query

The current status of LRN can be queried any time. The COM must be active to set the LRN flag. Setting the LRN flag with COM in-active is ignored. Setting the LRN mode using the serial command temporarily overrides the LRN mode setting established in ‘setup’. The value in ‘setup’ is restored on a power down/up or reset.

When LRN is set to on, each program will remember the last running gas flow when the program is disabled and use that gas flow the next time the program is enabled. When LRN is turned off, the program will always start with the originally programmed gas flow.

Command: LRN:<parameter>
Command: LRN?

Parameter/Response: 1 = ON, 0 = OFF

<parameter> can be separated from the command by l or less spaces.

Example: LRN:0<cr><lf>
Example: LRN:1<cr><lf>
Example: LRN?<cr><lf>

In VERBOSE, the response is “On”, or “Off”.

In TERSE, the response is “1”, or “0”, respectively.

7. Diagnostics

The following information is intended to facilitate troubleshooting of the Auto Controller and associated power supplies. This information assumes that the Auto Controller and power supplies are connected to power and that all interconnects between power supplies and the ion source cables have been manufactured correctly. It is also assumed that all gas connections are in good condition and that the gas circuit is complete from the gas bottle to the ion source.

Power must be removed from the Auto Controller and all other power supplies prior to performing maintenance.

7.1 Auto Controller

The auto controller front panel display has an additional function of displaying help codes and error messages. If it becomes necessary to display a help code or an error message, the Auto Controller may switch to standby mode depending on the particular code or message. The front panel display will alternate between displaying "HLP" and a number for the help code. The error messages will be displayed by alternating two abbreviated words. A description of the help codes and the error messages is given below in table 7-1 along with possible corrective action that may need to be taken.

Table 7-1. Help codes and error messages for the Auto Controller.

Help Code or Error Message	Description	Possible Causes And Corrective Action
HLP 7	Communication for remote RS-485 communication was detected and then lost.	Check the connections of the RS-485 cables. Make sure Keeper, Bias and Discharge Power Supplies have input power and are turned on. The HLP 7 message will automatically be cleared when communication is restored.
HLP 8	RS-232 Interface Serial Common Error. – High	Informational display only. No action taken on unit operation. Unit

Help Code or Error Message	Description	Possible Causes And Corrective Action
	current flowing in the ground connection of the serial interface between the unit and the Computer. Shows up only in remote RS-232 operation. Display says HLP 8 for 5 seconds.	recovers from error condition if problem goes away. Make sure all of the equipment has adequate grounding.
HLP 10	Start failed. – The discharge did not start.	Press and release the STANDBY/ENABLE button or remove the remote enable signal to clear the code. The unit remains in STANDBY until STANDBY/ENABLE is pressed again or the remote enable signal is reapplied. Anode has an insulating coating and needs to be cleaned. Hollow Cathode did not start. In this case, HLP 10 is also displayed on the Keeper Power Supply. In this case, review the HLP 10 message for the keeper supply below in table 7.2. For initial operation at a new operating condition, the gas flow may be too high or too low. Decrease or increase flow. Open or shorted discharge (anode) cable. Inspect in vacuum discharge cable and replace if necessary. Not all damage to the discharge cable may be apparent; in this case replacing the cable may be the only evidence the cable was faulty.

Help Code or Error Message	Description	Possible Causes And Corrective Action
HLP 11	Run Failed The discharge was started and went out.	Press and release the STANDBY/ENABLE button or remove the remote enable signal to clear the code. The unit remains in STANDBY until STANDBY/ENABLE is pressed again or the remote enable signal is reapplied. For initial operation at a new operating condition, the gas flow may be too high or too low. Decrease or increase flow. Open or shorted discharge (anode) cable. Inspect in vacuum discharge cable and replace if necessary. Not all damage to the discharge cable may be apparent; in this case replacing the cable may be the only evidence the cable was faulty.
HLP 12	Initial Gas Failure. The gas flow did not initialize during the start up sequence.	Press and release the STANDBY/ENABLE button or remove the remote enable signal to clear the code. The unit remains in STANDBY until STANDBY/ENABLE is pressed again or the remote enable signal is reapplied. Gas bottle is empty and needs to be replaced. Make sure that any valves in the system are open. MFC is faulty or MFC cable is faulty. Repair or replace MFC or cable.

Help Code or Error Message	Description	Possible Causes And Corrective Action
		Make sure MFC cable is connected.
HLP 13	Master Communication Error.	Switch off the power until the display is dark and then switch the power back on to reset.
HLP 14	Communication Failure.	Press and release the STANDBY/ENABLE button or remove the remote enable signal to clear the code. The unit remains in STANDBY until STANDBY/ENABLE is pressed again or the remote enable signal is reapplied. The system was running and then lost communication. Check the connection of the RS-485 cables. Power interruption to the power supplies. Make sure there is power to the power supplies and that they are turned on.
Int LOC	Open Interlock – An open interlock prevents the Auto Controller from going to the ENABLE state and holds it in STANDBY.	This is a user defined fault in remote operation. Review the interlock scheme for the system in question.
Not Rdy	Not Ready. – Auto Controller held in STANDBY.	Insufficient line voltage. Fault will clear itself when the Auto Controller receives sufficient line voltage.

7.2 Keeper Power Supply

The Keeper Power Supply front panel displays have the additional function of displaying help codes and error messages. If it becomes necessary to display a help code or an error message, the Keeper Power Supply may switch to standby mode, depending on the type of code or message. The front panel will display "HLP" and a number for the help code. The error messages will be displayed as one or two abbreviated words. A description of the help codes and the error

messages is given below in table 7-2 along with possible corrective action that may need to be taken.

Table 7-2. Help codes and error messages for the Keeper Power Supply.

Help Code or Error Message	Description	Possible Causes and Corrective Action
HLP 1	Current Latch – A high current was encountered. Power supply latched off to prevent a failure.	Switch off the power until the display is dark and then switch the power back on to reset
HLP 2	Thermal Failure.	Open or shorted thermistor detected. Contact KRI.
HLP 7	RS-485 Serial Communication Lost.	Communication for remote RS-485 communication was detected and then lost. Check connection of the RS-485 cables. Make sure Auto Controller has input power and is turned on.
HLP 8	RS-232 Interface Serial Common Error. – High current flowing in the ground connection of the serial interface between the unit and the PC. Shows up only in remote RS-232 operation. Display says HLP 8 for 5 seconds.	Informational display only. No action taken on unit operation. Unit recovers from error condition if the problem goes away. Make sure all of the equipment has adequate grounding.
HLP 10	Start failed. – The hollow cathode did not start.	Press and release the STANDBY/ENABLE button or remove the remote enable signal to clear the code. The unit remains in STANDBY until STANDBY/ENABLE is pressed again or the remote enable signal is reapplied.

Help Code or Error Message	Description	Possible Causes and Corrective Action
		Open or shorted cathode or keeper cables. Inspect the in vacuum cable and replace if necessary. No gas flow to the hollow cathode. Due to empty gas bottle, valve off somewhere in the gas supply, faulty MFC, or MFC cable damaged or unplugged.
Hot	Thermal Overload – Internal temperature in the power supply is too hot. Power supply is in STANDBY.	Leave the power supply turned on until the Hot message is cleared. Make sure there is no blockage of the vents on the rear panel. Ambient temperature is too high. Reduce ambient temperature below 40°C.
Not Rdy	Not Ready. – Keeper Power Supply is in STANDBY.	Insufficient line voltage. Message will clear itself when there is sufficient line voltage.

7.3 Bias and Discharge Power Supplies

The Bias and Discharge front panel displays have the additional function of displaying help codes and error messages. If it becomes necessary to display a help code or an error message, these power supplies may switch to standby mode, depending on the type of code or message. The front panel will display “HLP” and a number for the help code. The error messages will be displayed as one or two abbreviated words. A description of the help codes and the error messages is given below in table 7-3 along with possible corrective action that may need to be taken.

Table 7-3. Help codes and error messages for the Bias And Discharge Power Supplies.

Help Code or Error Message	Description	Possible Causes and Corrective Action
HLP 1	Current Latch – A high current was encountered. Power supply latched off to prevent a failure.	Switch off the power until the display is dark and then switch the power back on to reset
HLP 2	Thermal Failure.	Open or shorted thermistor detected. Contact KRI.
HLP 7	RS-485 Serial Communication Lost. – HLP 7 is displayed.	Communication for remote RS-485 communication was detected and then lost. Check connection of the RS-485 cables. Make sure Auto Controller has input power and is turned on.
HLP 8	RS-232 Interface Serial Common Error. – High current flowing in the ground connection of the serial interface between the unit and the PC. Shows up only in remote RS-232 operation. Display says HLP 8 for 5 seconds.	Informational display only. No action taken on unit operation. Unit recovers from error condition if the problem goes away. Make sure all of the equipment has adequate grounding.
Hot	Thermal Overload – Internal temperature in the power supply is too hot. Power supply is in STANDBY.	Leave the power supply turned on until the Hot message is cleared. Make sure there is no blockage of the vents on the rear panel. Ambient temperature is too high. Reduce ambient temperature below 40°C.

Help Code or Error Message	Description	Possible Causes and Corrective Action
Not Rdy	Not Ready. – Discharge Power supply is in STANDBY.	Insufficient line voltage. Fault will clear itself when the power supplies receive sufficient line voltage.

8. LIMITED WARRANTY

Kaufman & Robinson, Inc. (KRI) warrants to the purchaser or end user of the equipment it sells that such equipment will be free from defects in material and workmanship under normal use and service. This warranty is for a period of two years from the date of original shipment F.O.B KRI's facility, Fort Collins, Colorado. This warranty is void if the equipment is not used, operated, and maintained in accordance with the manual accompanying the equipment. KRI shall not be responsible for any direct or indirect loss or damage resulting from accident, negligence of a user, alteration, abuse, or misuse of the equipment. Upon acceptance of this Limited Warranty, purchaser waives all warranties, guarantee, or remedies not specifically stated in this Limited Warranty. This warranty does not cover ordinary wear and tear or expendable components.

KRI's obligation under this Limited Warranty is, at KRI's option, to repair or replace any defective equipment or parts of the equipment, without charge to the purchaser, which are returned, shipping prepaid, to the KRI facility, 1306 Blue Spruce, Unit A, Fort Collins, Colorado, 80524 USA. For return or repair of equipment, purchaser must contact KRI for a Return Materials Authorization prior to shipment of the equipment to KRI. If KRI has designated an Authorized Warranty Service Representative in the purchaser's country, contact may be made with the Authorized Warranty Service Representative and defective equipment may be delivered to such Authorized Warranty Service Representative to service warranty claims.

This warranty is in lieu of all other warranties, expressed or implied, including the implied warranties of merchantability and fitness for any particular purpose. The purchaser acknowledges the purchaser is not relying in KRI's skill or judgment to select or furnish equipment suitable for any particular purpose.

This Limited Warranty will be construed in accordance with the Uniform Commercial Code as adopted by the State of Colorado.

This warranty does not cover expendable parts; examples of expendable parts are as follows:

Alumina Insulators, hollow cathode inserts, Reflectors, Gas Line Isolator, Vacuum Cables and fuses.

9. SERVICE AND TECHNICAL INFORMATION

For technical information, repairs or replacement during Warranty, or repairs thereafter, please contact:

Kaufman & Robinson, Inc.
1306 Blue Spruce Dr.
Fort Collins, CO 80524
Tel.: 970-495-0187
Fax.: 970-484-9350
www.ionsources.com

Please include the following details relating to the problem encountered or the item to be returned:

- Product
- Serial number
- Detailed description of problem
- Date of purchase
- Name and address of company
- Contact person

If return to KRI is required, you will be given an authorization number and instructed where to send it.