eH2000 HOLLOW CATHODE WATER-COOLED ANODE ION SOURCE MANUAL

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Kaufman & ROBINSON
Ion Beam Authority[sm]

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WARNING:
Danger of high voltage personal injury.

WARNING:
Indicates death, serious injury, or property damage can result if proper precautions are not taken.

CAUTION:
Indicates death, serious injury, or property damage can result if proper precautions are not taken.

1. SAFETY

WARNING:
Manual should be read before you install, operate, or maintain this product. Failure to follow instructions can lead to personal injury and/or property damage. If the equipment is used in a manner not specified by KRI, the protection provided by the equipment may be impaired. Hazardous voltages exist within the product and at the outputs. Only technically qualified personnel should install, maintain, and troubleshoot the equipment described herein. There are no user serviceable parts inside the product.

Troubleshooting and maintenance should be carried out only after grounding the components to be worked on and assuring that power cannot be applied to those components while working on them.

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2. INSPECTION AND INSTALLATION

This chapter describes how to install the Kaufman & Robinson, Inc., KRI® eH-2000HC water-cooled anode ion source. Unpacking and inspection, physical description, hardware inventories and installation information is provided to assist in facilitating a successful installation.

2.1 Unpacking and Inspection

Prior to shipment, the ion source was inspected and tested, and was shipped free of defects. As soon as the ion source has been completely removed from all packing materials, a visual inspection should be made to determine if there has been any damage during shipment. If any damage has occurred, contact KRI®, in addition to the shipping company to report any damage (see Limited Warranty Chapter 9). Retain packaging materials for shipment of the ion source.

CAUTION:
All ion source hardware was cleaned prior to shipment, use clean lint free gloves while handling all components to prevent contamination.

2.2 Physical Description

The following describes the ion source and feedthroughs needed to operate the ion source in detail.

2.2.1 eH2000HC Ion Source

The eH2000HC ion source has been designed using a modular approach in order to provide a durable product that is easy to maintain, assemble and disassemble. The ion source has been fabricated primarily of stainless steel and alumina hardware. Depending on the intended use of the ion source, titanium or graphite parts may also be installed.

The source was designed for ease of maintenance, in addition to the modular construction, threaded parts are mostly oversized and in some cases gold plated to prevent galling. Do not over-tighten threaded parts. Finger-tightening should be adequate for most threaded parts. Wrenches should be used only when there is unusual resistance. The threaded parts most likely to gall and seize were also made small enough that they can be broken off and replaced with new nuts and screws.

The ion source has a height and diameter of 13.9 cm x 14.4 cm (5.5 in x 5.7 in), and a mass of 3.8 kg (8.5 lbs.). The ion source can be mounted to the transit support assembly or free standing.

2.2.1.1 Anode Module

The anode module is easily removed from the main module in this design so that minimal effort is needed to perform maintenance on the ion source (Figure 2-1). Alignment of the two modules is facilitated using alignment notches and support hardware. Gas and electrical connections to the anode module are made when the module is connected to the main module.

2.2.1.2 Main Module

The main module contains the magnetic circuit, electrical connections and associated support hardware for the anode module (Figure 2-1). Electrical and gas connections are made to the source at the main module. A vacuum cable from the electrical feedthrough connects to the ion source at the outer shell in this module. The main module has been designed so that minimal maintenance is required.

2.2.1.3 Dual Water Break

The dual water break connects to the two-piece outer cylinder, as well as the anode module. The water connection in/out is made here (Figure 2-1). The dual water break has been designed with minimal parts for ease of service.

2.2.2 Electrical Feedthrough Assembly

KRI® offers different electrical feedthrough options depending on different application needs. The following information details the standard options KRI® provides.

2.2.2.1 2¾" ConFlat Flange Feedthrough

The 2¾" ConFlat (CF) flange is typically used in applications where high vacuum pressure is needed. The dimensions, details, and pinouts for this feedthrough can be seen in Figures 2-2 through 2-4.

2.2.2.2 1" Bolt Feedthrough

The 1” bolt feedthrough is standard feedthrough with wiring schematic similar to the CF flange. The dimensions, details, and pinouts for this feedthrough can be seen in Figures 2-5 through 2-7.

2.2.2.3 LEMO Feedthrough

The LEMO feedthrough is a 1” feedthrough designed for easy implementation and use. The dimensions, details, and pinouts for this feedthrough can be seen in Figure 2-8.

2.2.3 Vacuum Cables

Vacuum cables have been supplied for the anode and cathode connections that are made from the electrical feedthrough to the ion source. These cables have been fabricated using fiberglass loom, alumina insulators, and a copper conductor. These cables provide electrical shielding from grounded surfaces and prevent the accumulation of sputtered material on the enclosed insulators.

2.2.4 Gas Feedthrough

KRI® offers two different types of gas feedthroughs, a 2¾” CF flange feedthrough, and a 1” bolt feedthrough. See Figure 2-9 for dimensions and details for both feedthroughs.

2.2.5 Water Feedthrough

KRI® offers two different types of water feedthroughs, a 2¾” CF flange feedthrough, and a 1” bolt feedthrough. See Figure 2-10 for dimensions and details for both feedthroughs.

2.3 Inventory

The following table, Table 2-1, outlines the required hardware necessary for installation and operation of the ion source. The serial number for the ion source is stamped on the main module inside of the ion source. This serial number will indicate whether the ion source has been configured for inert or reactive gas. Example: A serial number of WC-1404CRSXXX indicates that the ion source is an eH2000HC ion source, hollow cathode version, configured for reactive gas using a stainless steel reflector, with a water-cooled anode. The letter R or I in the serial number indicates the type of gas (reactive or inert), while the last letter of the serial number indicates the type of reflector installed when the ion source was shipped. This designator can be S, C, or another designator for reflectors offered by KRI®.

The reflector can be changed to accommodate operation with inert and reactive gases. The material of the reflector can be either graphite for inert gases or stainless steel for reactive gases, or a combination of reactive and inert gases (i.e. a mixture of argon and oxygen gas). The different materials are used to limit the erosion rate of the reflector with each type of gas. If contamination is a concern, other types of reflector material are also available from KRI®.

If the ion source will be used with a gas other than what it was originally specified for, the reflector must be changed prior to operation. An alternate reflector has been supplied. Refer to the relevant parts list in the Maintenance Section 7 for part numbers and descriptions.

Table 2-1. Inventory List

Quantity	Description
1	End-Hall 2000 ion source
1	Dual water break
1	Vacuum discharge cable
1	Gas line
2	Water line
1	Electrical feedthrough assembly
1	Feedthrough, gas
1	Feedthrough, water
1	Spare reflector, gas
1	Spare reflector, stainless steel
1	Spare parts kit

2.4 Installation

The eH2000HC ion source is typically installed at a source to substrate distance of 30 cm (12 in).

CAUTION:
Use clean lint free gloves to handle any of the components to preven contamination.

Contamination of the ion source is a consideration. Line-of-sight deposition on the surface of the ion source, such as from an e-beam evaporator, should be minimized. There should be no line-of-sight deposition on the anode or the cathode. If necessary, a sheet-metal baffle can be placed between the ion source and the source of deposited material.

The magnetic field should also be small at the location of the ion source. It is recommended that the magnetic field be less than 10 Gauss at the desired location prior to installing the ion source. It may be possible to reduce this field by installing a permeable plate (e.g., a 1-2 mm thick sheet of low-carbon steel) between the ion source and the source of the magnetic field and oriented approximately perpendicular to the line-of-sight between them. Refer to Chapter 6 for further considerations regarding placement of the ion source within the vacuum facility.

2.4.1 Ion Source Mounting

Installation of the ion source and associated hardware can be facilitated with the use of Figure 2-2 through Figure 2-13. Standard installation procedures used in the vacuum industry should be adhered to when installing vacuum fittings and feedthroughs. All components shipped have been cleaned prior to shipment.

The ion source has been designed for ease of installation. Four ¼-20 threaded holes have been provided at the ion source back plate for attachment to vacuum chamber bracketing or to the optional transit support, Figure 2-14. In the event that all four holes are not used in the mounting of the ion source, the remaining holes must be plugged using ¼-20 × ¼” screws or set screws.

An optional transit support assembly has been designed to assist in mounting the ion source. On one side of the support there are mounting holes that correspond to mounting holes in the back plate of the ion source. The dimensions for these mounting holes in the transit support are the same as the corresponding holes in the ion source and the dimensions are shown in Figure 2-14. Mounting holes are also provided in the transit support for installation in the vacuum facility. The locations of these mounting holes are shown in Figure 2-15. The transit support has been designed so that the angle of the ion source relative to the mounting of the transit support, can be changed, zero to ninety degrees, in 5 degree increments.

2.4.2 Hollow Cathode Mounting

The hollow cathode is attached to the ion source using a mounting bracket that has been supplied. This bracket should already be attached to the hollow cathode. The mounting bracket is secured to the ion source at one of the two hold down rods that extend through the ion source front plate. Remove one of the two acorn nuts at the front plate and attach the hollow cathode bracket to the ion source then replace and tighten the acorn nut, Figure 2-16 shows the location of these nuts. The acorn nuts prevent deposition on the threads, which would otherwise be exposed.

2.4.3 Gas

All of the fittings, for constructing the gas circuit, were cleaned prior to shipment and should be handled using clean, lint free gloves. Use 304 stainless steel tubing (passivated to ASTM A967 certification) when fabricating and installing all gas lines. Failure to use clean gas lines and fittings will contaminate the hollow cathode, resulting extremely low insert lifetimes. Gas connections can be made with reference to Figure 2-9 and Figures 2-11 through 2-13.

The eH2000HC source can be operated on different gases. These gases must be 99.999% pure.

Gas connections are made to the eH2000HC source using Swagelok™ fittings. A mass flow controller is used to regulate the gas flow to the ion source. Once the gas circuit has been completed from the ion source to the gas bottles, the gas line should be evacuated to prevent contamination of the gases and the ion source.

While installing the mass flow controller, gas bottle, and gas line, atmospheric gases can become trapped within the gas circuit. It is necessary to remove this trapped volume of gas in the correct manner. Each time a gas bottle is changed or the gas circuit is modified, the following procedure should be used:

- A two-stage, high purity pressure regulator should be used. Connections to the gas flow controller and the vacuum chamber wall should be made with clean passivated (see above) stainless steel tubing. **Note:** Do not us plastic tubing, which will lead to extremely low insert lifetimes.

- Attach the gas bottle to the pressure regulator. **Do not open the valve on the gas bottle.**

- Evacuate the vacuum chamber to the base pressure.

- While keeping the gas bottle valve closed, fully open the pressure regulator. Leaving the flow controller closed, open any other valves between the pressure regulator and the vacuum chamber.
- Slowly increase the gas flow from zero to maximum while monitoring the vacuum chamber pressure. If the flow is increased too rapidly, the gas load may be sufficient to overload the pumping capability.
- If more than one flow controller is used on the same gas bottle, apply these instructions to all flow controllers and associated valves.
- Leave the flow controller open until the vacuum chamber pressure has returned to the base pressure - typically 15 minutes.
- Close the pressure regulator and flow controller.
- Open the gas bottle valve.
- Adjust the pressure regulator to give normal pressure after the regulator (usually about 140 kPa gauge or 20 psig).
- Adjust the flow controller to give a flow of at least 10 sccm (standard cubic centimeters per minute).
- Maintain this flow for at least 15 minutes.
- Stop the flow by reducing the flow with the flow controller. The gas bottle is now ready for normal operation.

2.4.4 Water

All of the fittings for constructing the water circuit, were cleaned prior to shipment and should be handled using clean, lint free gloves. Use clean Stainless steel, copper, nickel or some other temperature tolerant tubing when fabricating and installing all water lines. Water connections can be made with reference to Figures 2-10 through 2-13.

The water-cooled anode will require a minimum flow rate of 2 liters/minute (approximately 0.5 gallons/minute). The water outlet temperature flowing from the anode should be no higher than 45°C.

Water quality should have a minimum resistivity of 11,000 ohm•cm or higher. Distilled water is recommended.

2.4.5 Electrical Connection in the Vacuum System

2.4.5.1 Ion Source

The electrical connection for the anode (or discharge connection) is made from the vacuum feedthrough to the ion source using the discharge cable supplied. The connection to the ion source is made on the outer cylinder, near the back plate and gas connection. The anode connection is made in the center clearance hole as shown in Figure 2-1 and Figure 2-16. The cable end that mates with the ion source has a ceramic cable end which encloses most of the inner female connector. This female connector mates to a plug located within the ion source. The opposite end of the discharge cable connects to the vacuum feedthrough, see Electrical Feedthrough Connections, Vacuum Side.

2.4.5.2 Hollow Cathode Connection

Electrical connection to the hollow cathode is made using two cables (bias and keeper). These cables are fabricated using a copper conductor with alumina bead insulators and fiberglass loom to provide electrical shielding as well as shielding of the beads from deposited materials.

The bias cable connects from the feedthrough to the hollow cathode at the hollow cathode gas line. The keeper cable connects to the hollow cathode on the hollow cathode body. Both connections can be seen in Figure 2-16.

2.4.6 Electrical Feedthrough

Figures 2-11 through 2-13 show the installation of the EH2000 and a KRI® hollow cathode electron source using each standard electrical feedthrough. Using standard vacuum practice, install the electrical feedthrough.

2.4.6.1 Electrical Feedthrough Connections, Vacuum Side

Connections from the ion source are made to the electrical feedthrough as follows with the use of Figure 2-1 through 2-13. Follow the proper pinout and connection location when making cable connections to ensure proper working use of the ion source.

2.4.6.2 Electrical Connections at Atmosphere

An operating cable has been provided for connection from the power supplies to the feedthrough. See the installation drawings in Figures 2-11 through 2-13 to ensure proper cable connections between the controllers and the feedthrough.

Note: The green ground wire on the power supplies that needs to be connected to the vacuum chamber wall (Figures 2-11 through 2-13). For electrical connections at the power supplies refer to the power supply manual.

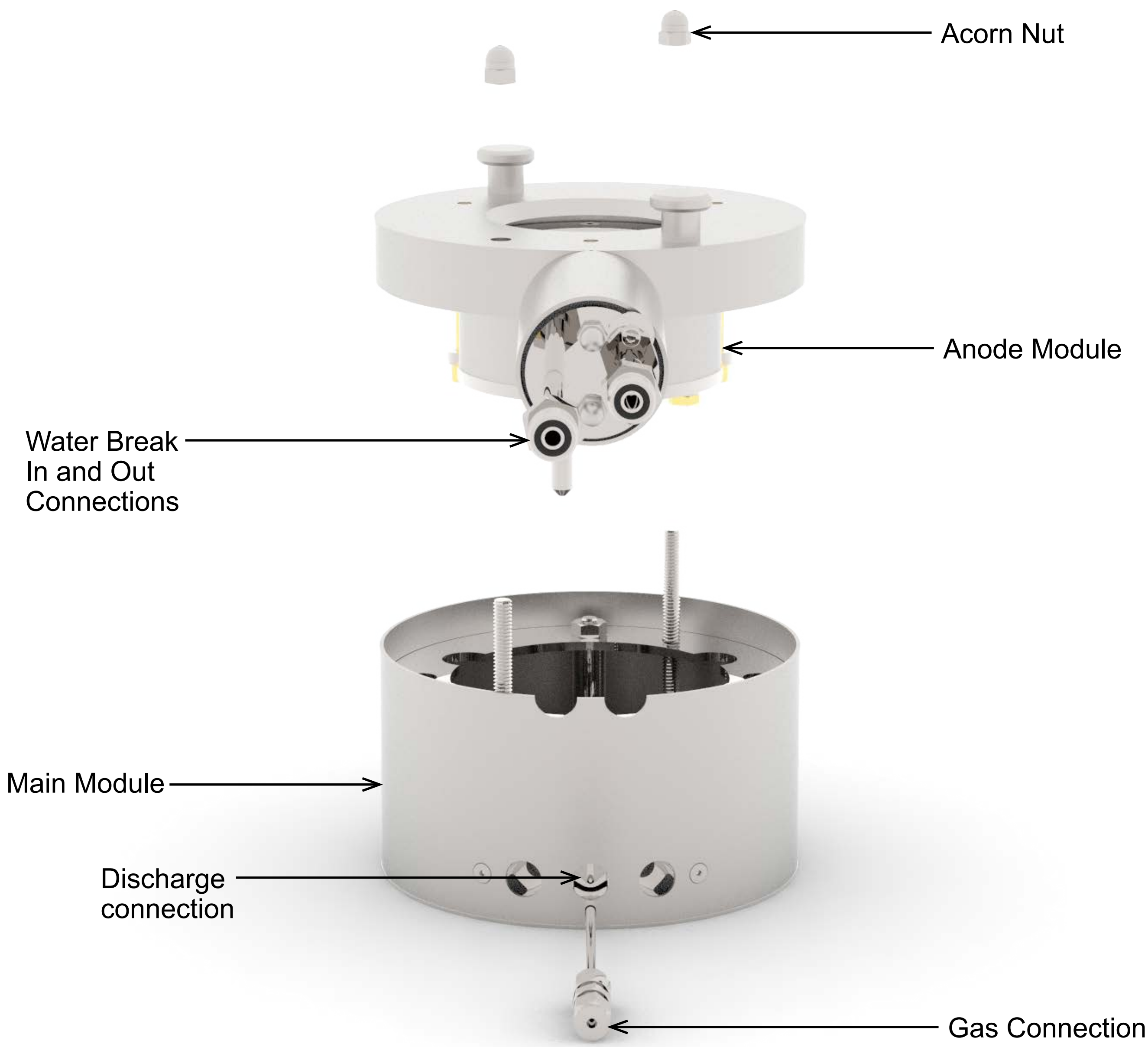


Figure 2-1. The eH2000HC water-cooled anode ion source with the anode module removed.

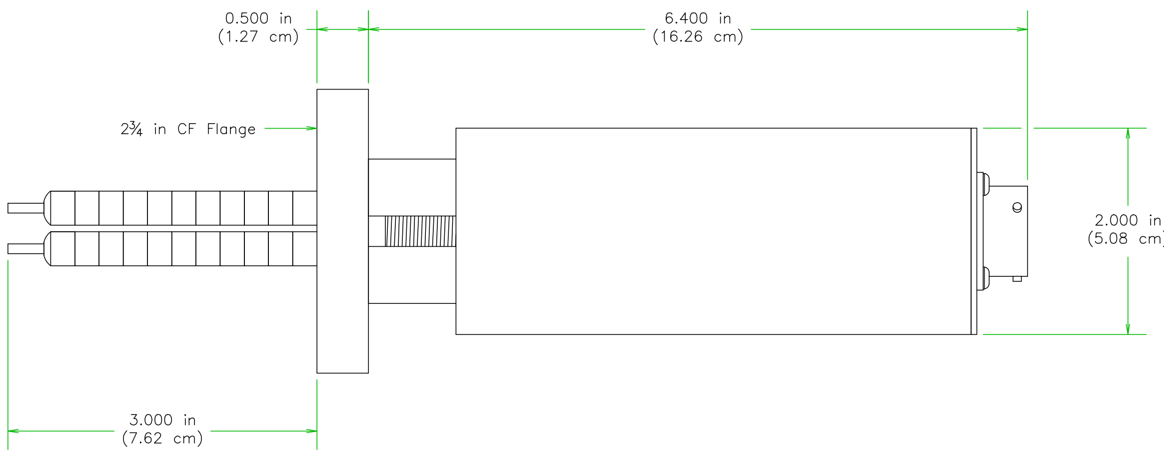


Figure 2-2. 2¾ CF feedthrough dimensions.

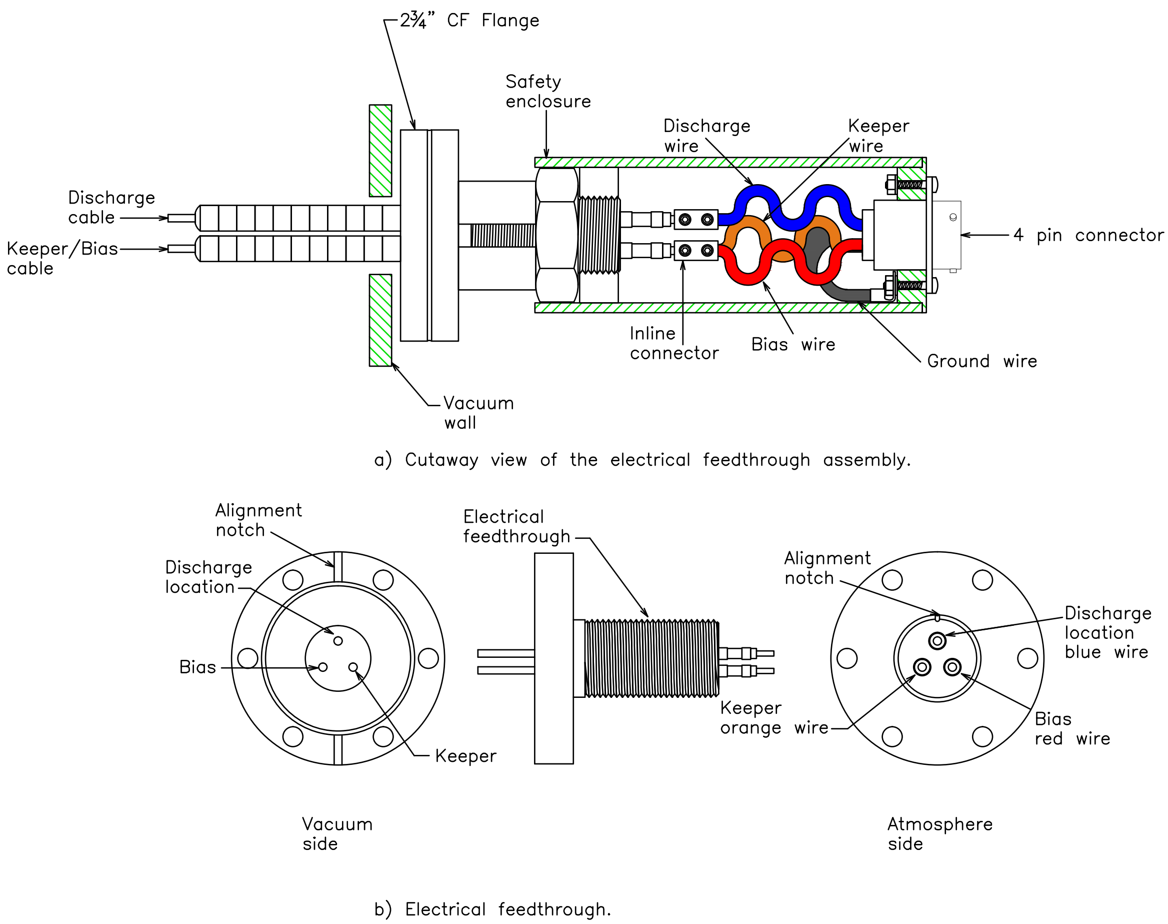
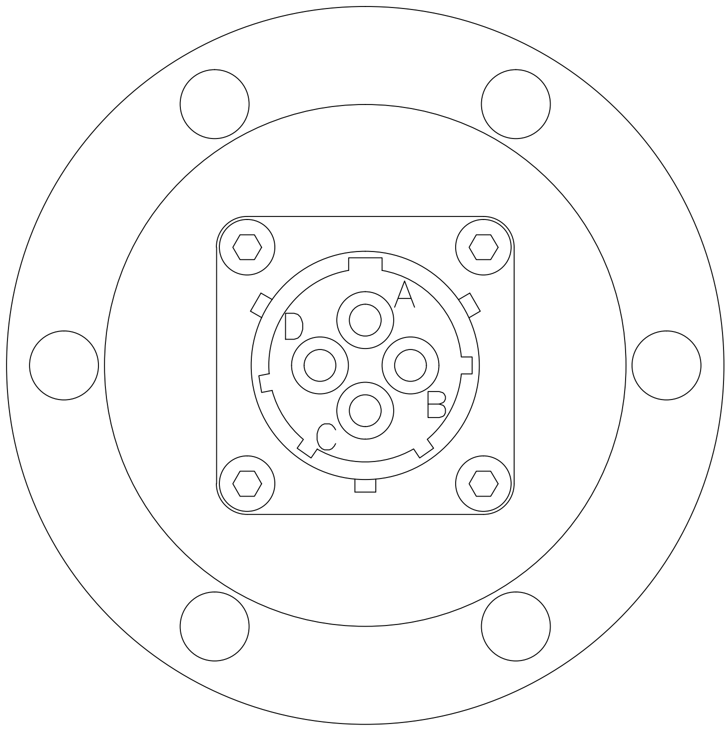


Figure 2-3. 2¾ CF feedthrough details.



Pin	Wire Color	Description
A	Blue	Discharge
B	Red	Bias
C	Black	Ground
D	Orange	Keeper

Figure 2-4. Electrical connection pinouts for 2¾ inch CF flange feedthrough.

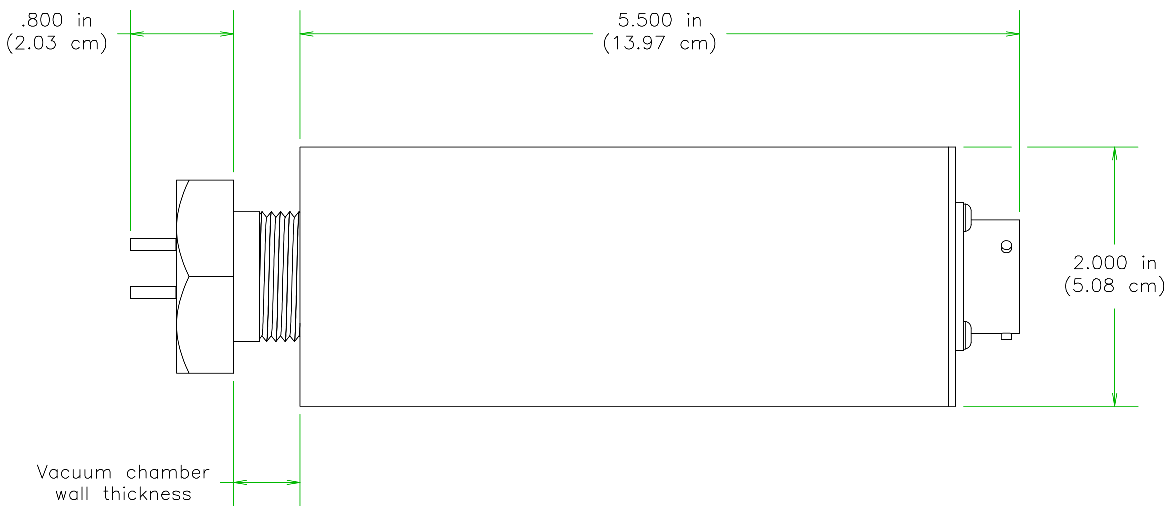


Figure 2-5. 1 inch bolt feedthrough dimensions.

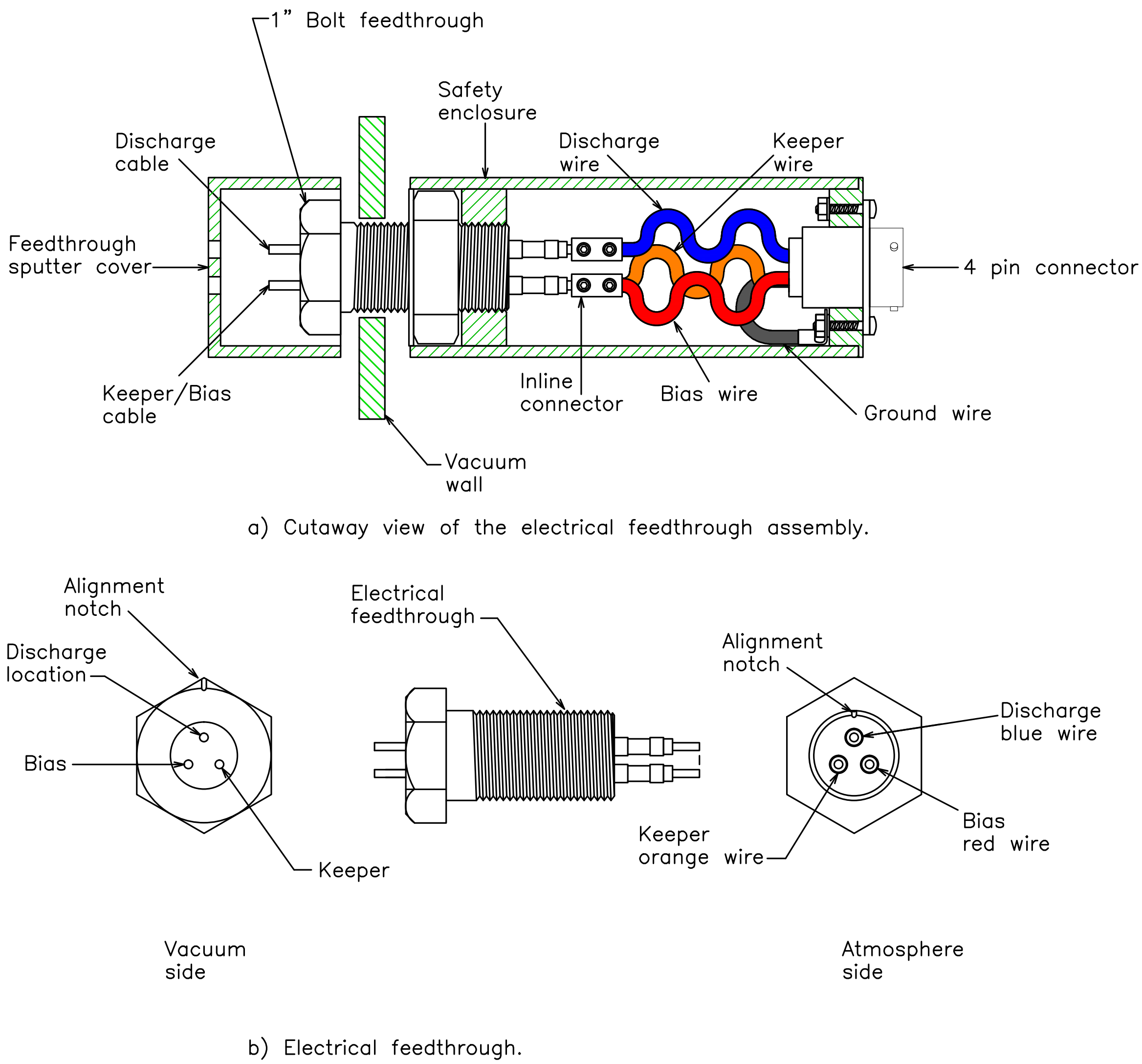
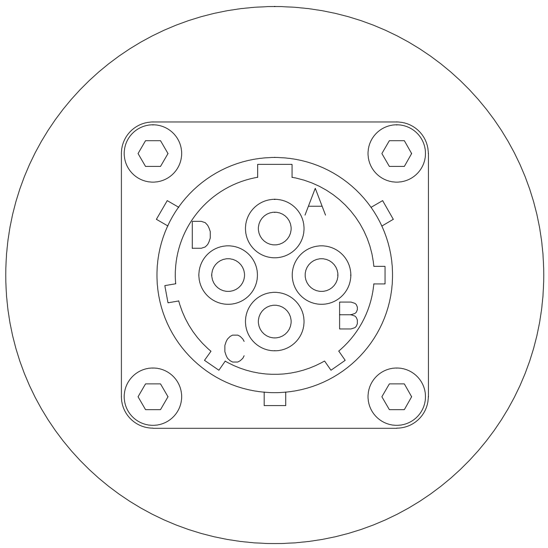


Figure 2-6. 1 inch bolt feedthrough details.



Pin	Wire Color	Description
A	Blue	Discharge
B	Red	Bias
C	Black	Ground
D	Orange	Keeper

Figure 2-7. Electrical connection pinouts for 1 inch bolt feedthrough.

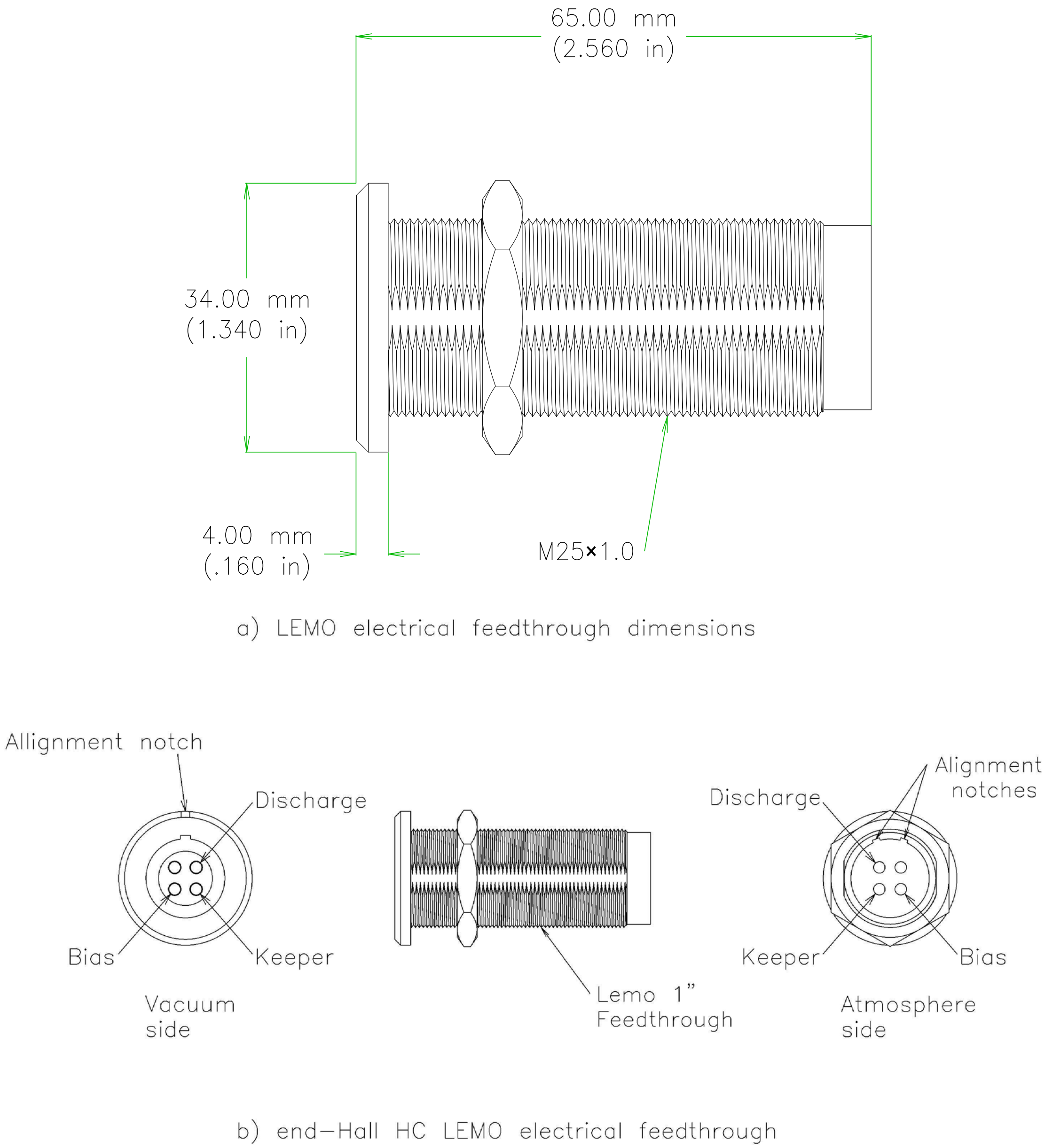
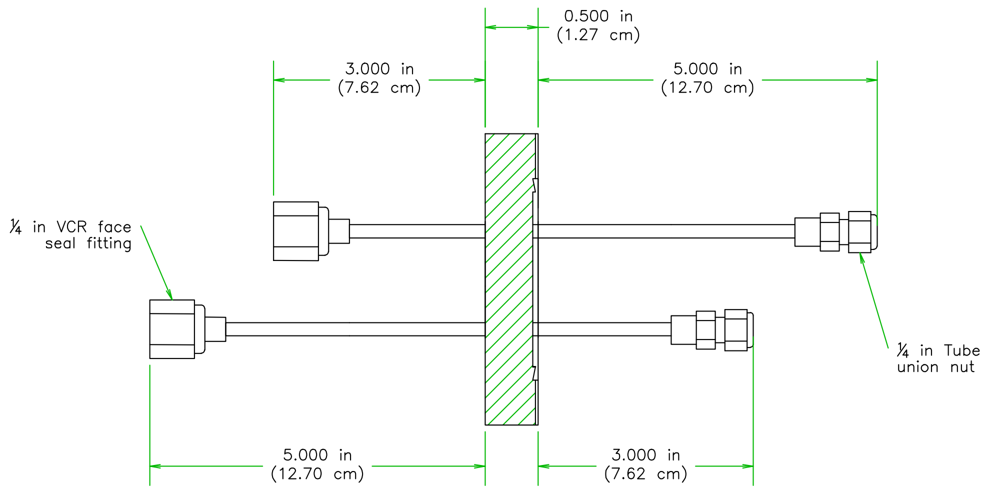
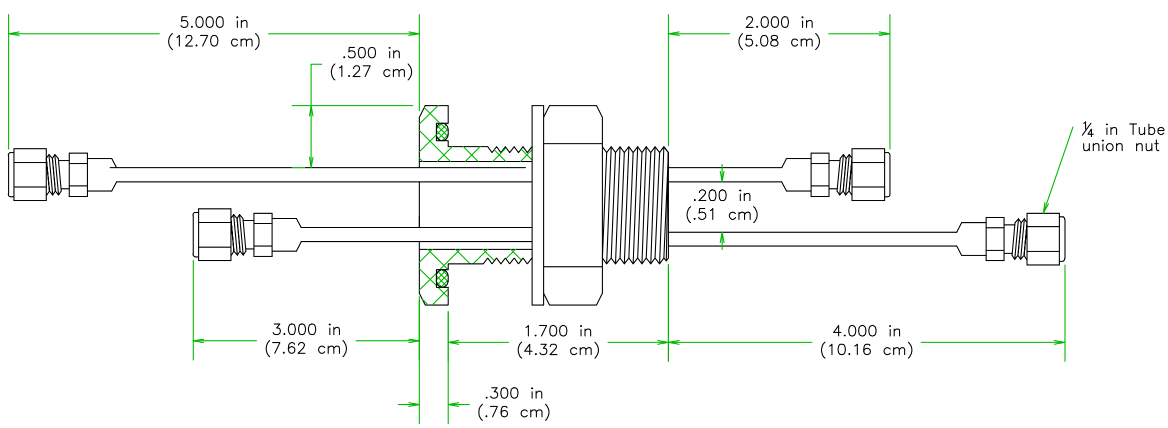


Figure 2-8. LEMO feedthrough dimensions and pinouts.

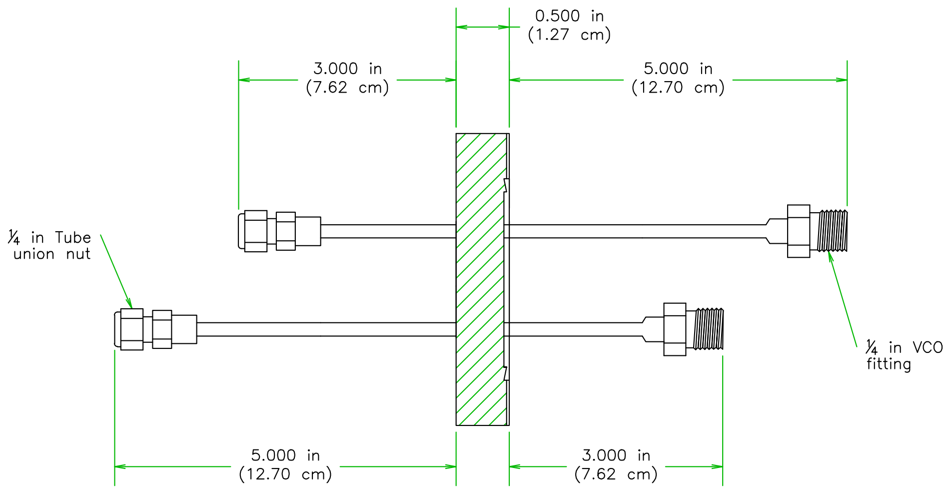


a) 2¾ inch CF flange gas feedthrough

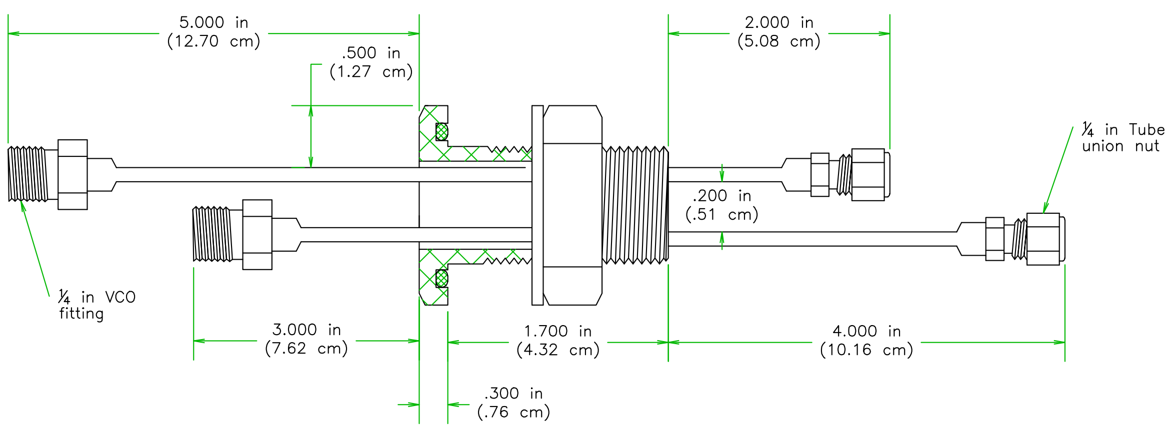


b) 1 inch bolt gas feedthrough

Figure 2-9. Gas feedthrough dimensions.



a) 2¾ inch CF flange water feedthrough



b) 1 inch bolt water feedthrough

Figure 2-10. Water feedthrough dimensions.

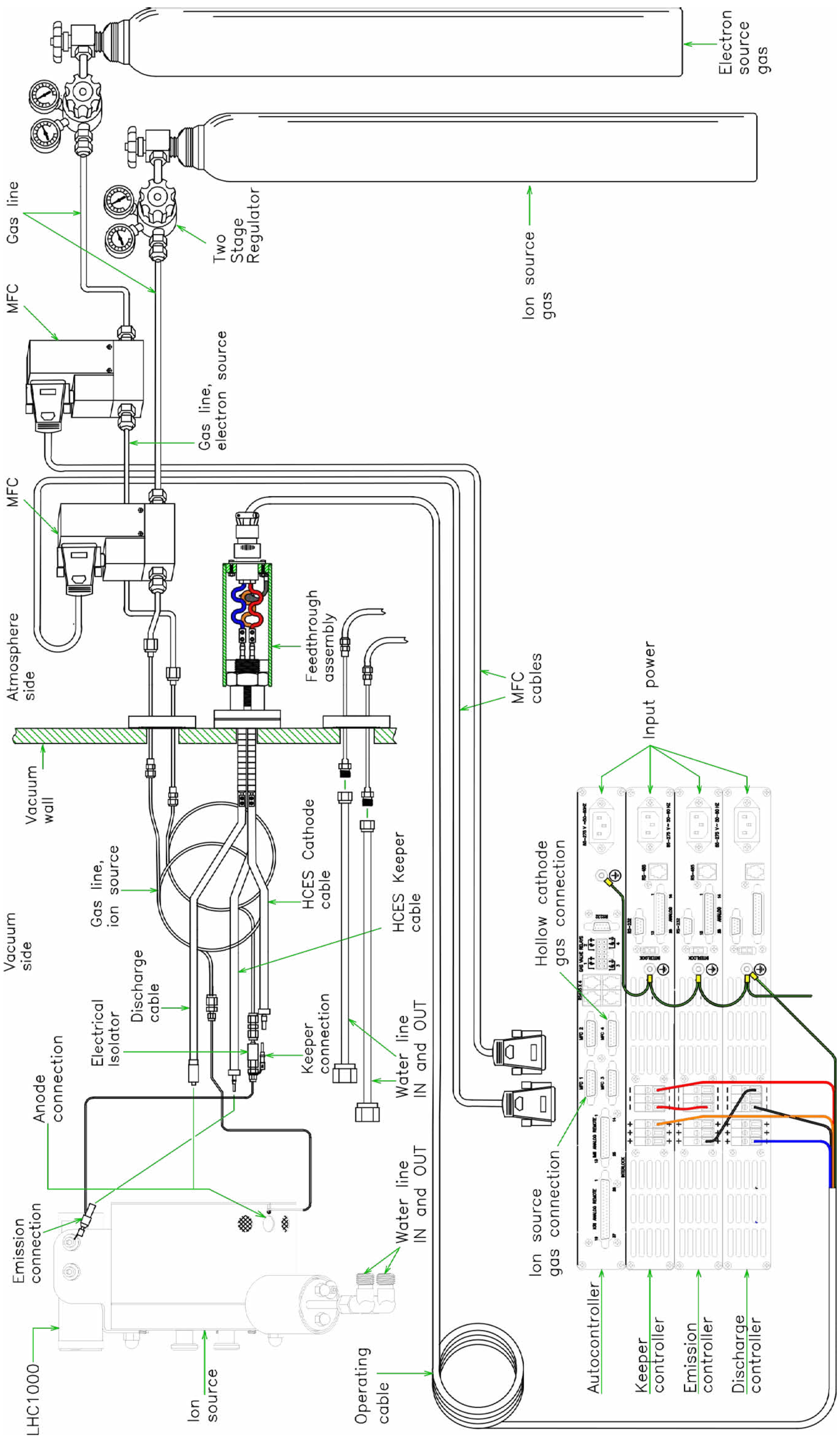


Figure 2-11. Installation drawing for the eH2000HC with CF flange feedthroughs.

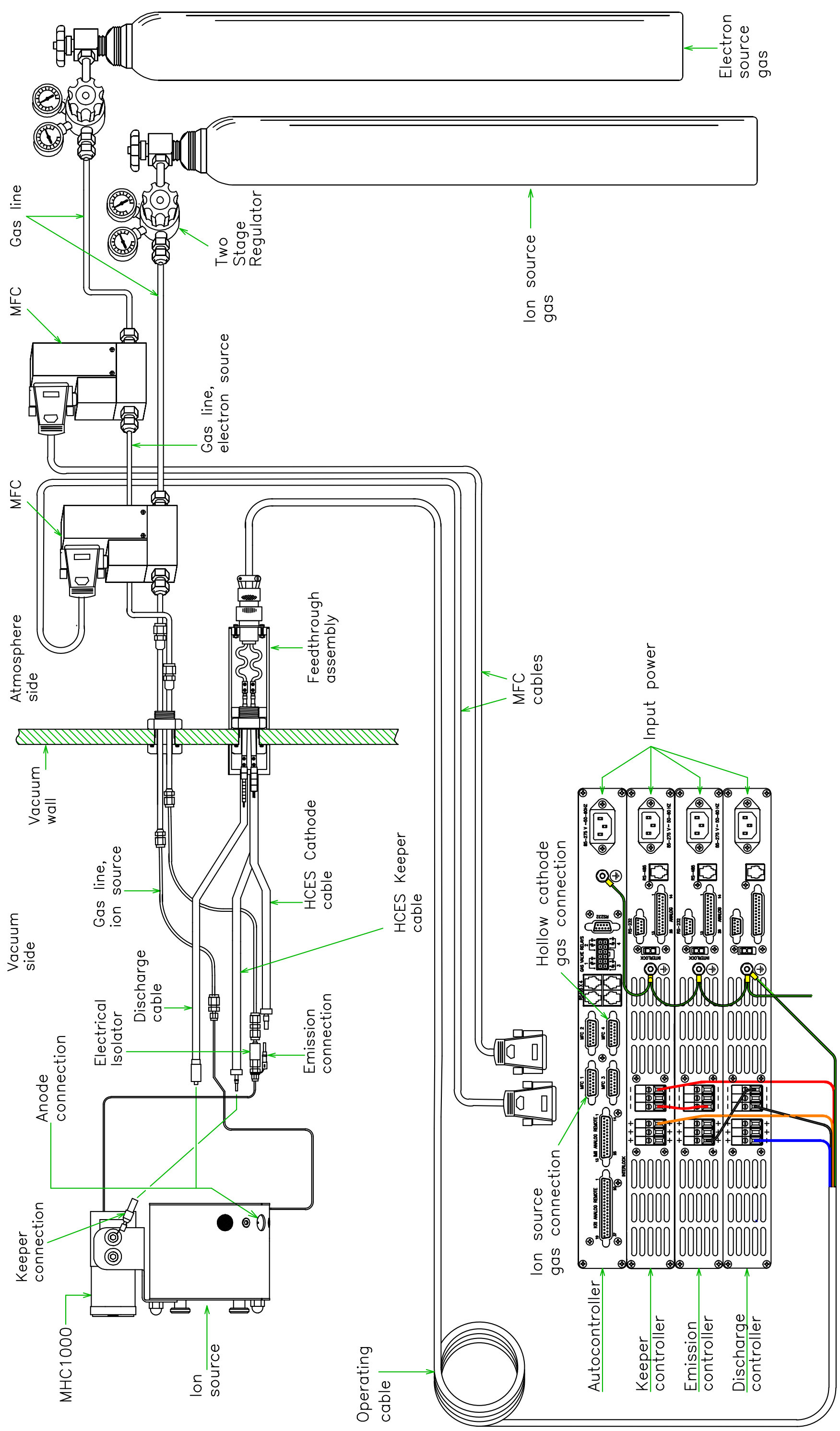


Figure 2-12. Installation drawing for the eH2000HC with 1 inch bolt feedthroughs.

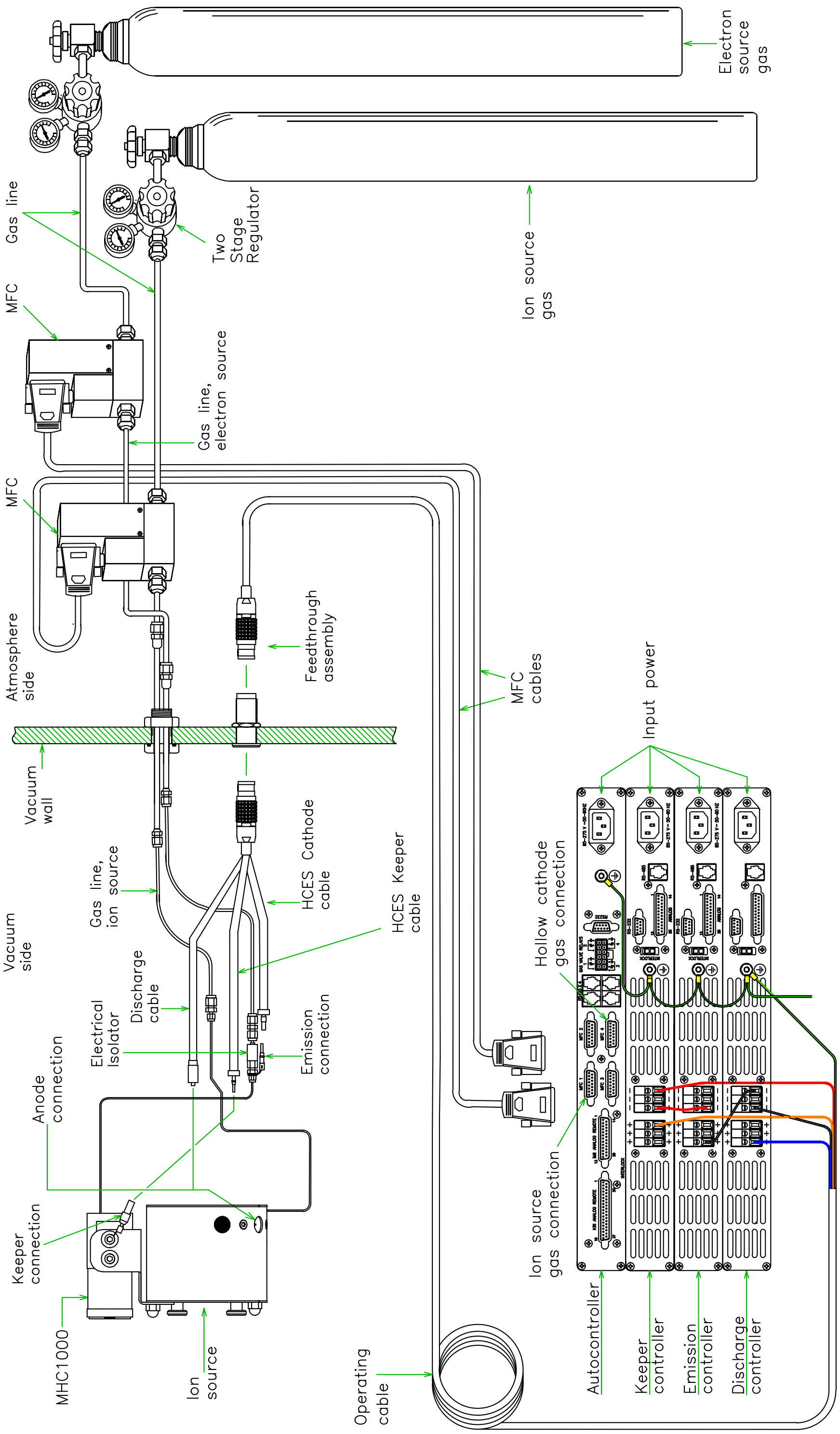


Figure 2-13. Installation drawing for the eH2000HC water-cooled anode with LEMO feedthroughs.

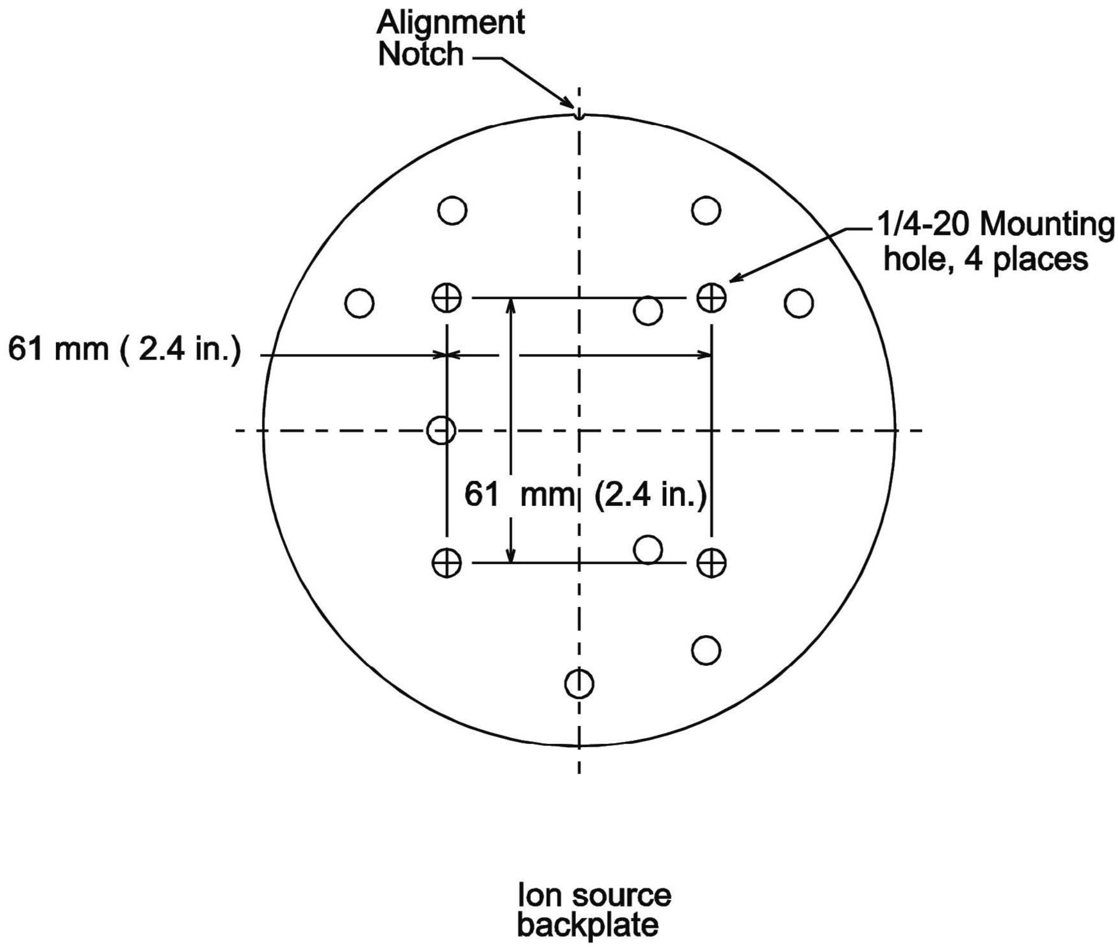


Figure 2-14. Mounting hole locations for the eH2000HC ion source.

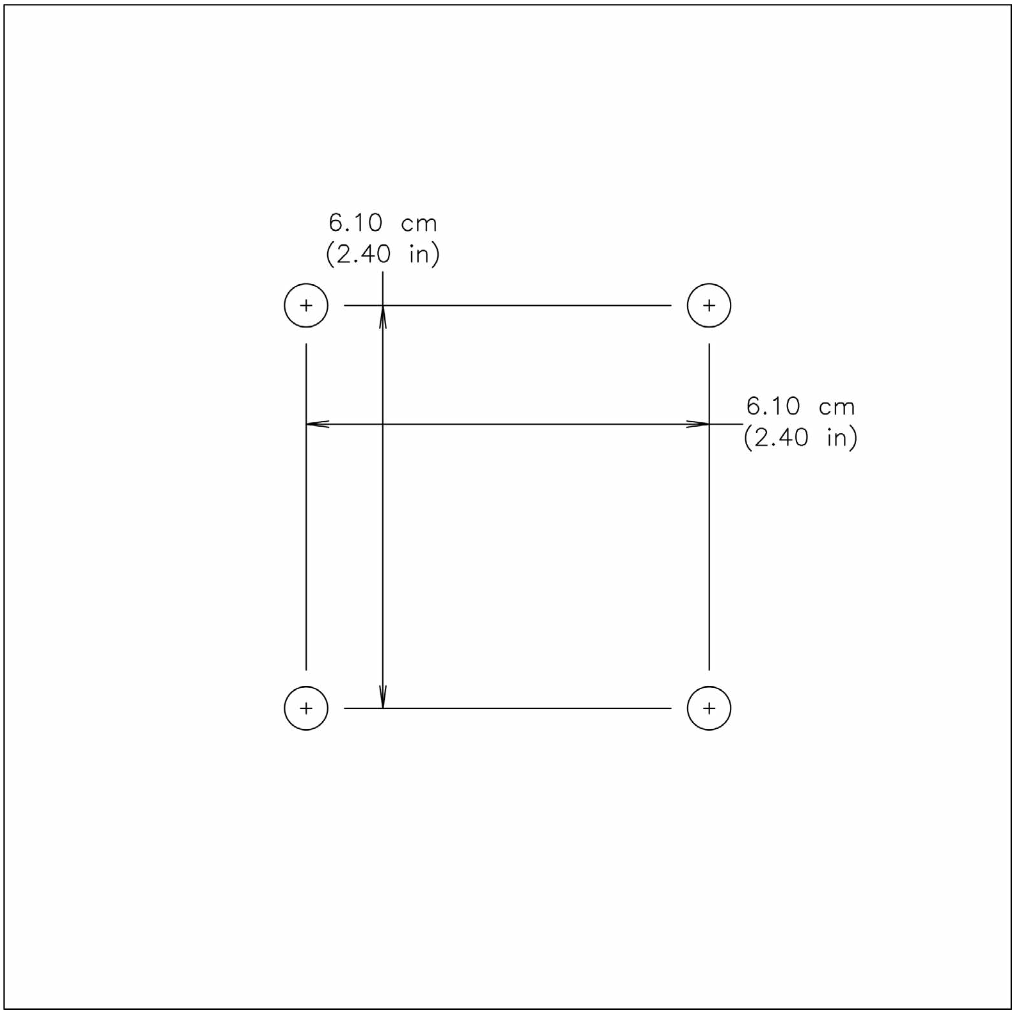


Figure 2-15. Mounting hole locations for the (optional) transit support.

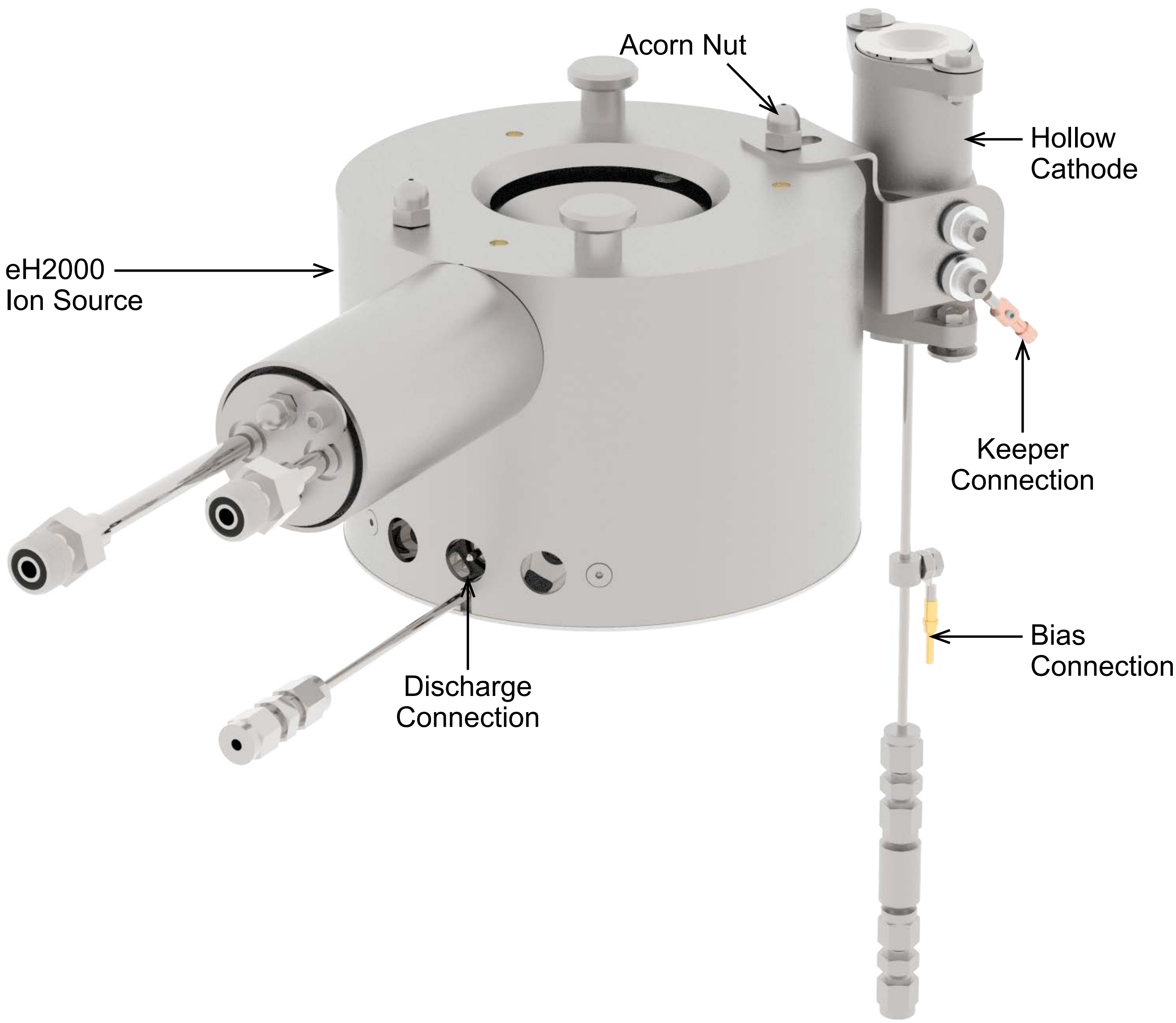


Figure 2-16. Hollow cathode mounting and connections

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3. APPLICATION CONSIDERATIONS

3.1 Coverage Calculations

The ion beam profiles shown in Section 6 can be used to determine coverage. For source to substrate distances other than shown, the width of the profile should be varied proportional to the source-substrate distance and the ion current density varied inversely as the square of that distance.

In general, cleaning and ion assist applications require some minimum dose or rate. But a moderate excess over this minimum usually has no significant effect. Coverage calculations should therefore focus on substrate locations where the ion current density is low.

3.2 Cleaning

It is useful to think of two types of cleaning: removing an initial contamination that is not replaced, or removing a contamination that is replaced at a constant rate.

3.2.1 Initial Contamination

A frequent contamination is adsorbed water vapor and hydrocarbons from the laboratory environment. Such contamination reduces the adhesion of any deposited film, but is easily removed. Any moderate ion energy is sufficient to desorb such a contamination and the density of ions striking the surface to be cleaned is more important than the energy of those ions. An ion dose of about one mA-sec/cm2 should be adequate to remove such contamination. In other words, an ion bombardment of one mA/cm2 could be continued for one second, or one of 0.01 mA/cm2 could be continued for 100 seconds.

The more adherent the contamination, the larger the dose that must be used. One of the more difficult contaminations to remove is an oxide, which can also require higher energies to sputter the adherent contamination. Tables of sputter yields should be used to estimate the ion dose required for such cleaning.[1]

3.2.2 Continuing Contamination

The vacuum chamber environment may contain significant contamination, such as water vapor continuously desorbing from vacuum chamber surfaces, so that the contamination is continually deposited. The level of this contamination is approximately indicated by the base pressure reached after pump-down and before any process gas is introduced. The adherence and quality of deposited films can benefit from a continued low level of ion bombardment.

3.3 Ion Assist

In addition to the cleaning function described above, ion bombardment during the deposition of a thin film can increase properties such as density, hardness, refractive index, resistance to environmental degradation, as well as control stress. The effectiveness of the ion beam depends on both the arrival rate of ions and the mean energy of these ions, and is at least approximately correlated by the average ion energy per film atom deposited. Depending on the specific ion assist application, a range from several eV/atom up to about 100 eV/atom has been found useful.[4]

4. ELECTRICAL DESCRIPTION

The information presented in this chapter should be adequate for a general understanding of the operation of the eH2000HC water-cooled anode ion source. More detailed information on the controller is presented in the manual for the controller.

4.1 Schematic Diagram

Operation of the eH2000HC Water Cooled Anode Ion Source is described in summary form, it can be generally understood by reference to the block diagram of Figure 4-1. This description assumes that the power supplies have been preset to the operating conditions to be used, as outlined in the manual for the ion source controller. Operation of the ion source starts with a working gas introduced into the ion source.

The hollow cathode current is then increased to a value sufficient enough to facilitate the ion source discharge starting.

A voltage is then applied to the anode (discharge) of the ion source. Once this voltage is applied, electrons will flow toward the anode of the ion source but are prevented from flowing directly to the positive anode by the magnetic field generated by the ion source's magnet. The electrons created by the emission bombard the molecules of the working gas in the anode region of the ion source which result in ions. Most of the ions are generated in the area within the anode.

The gaseous mixture of electrons and ions in this region constitutes a plasma. A potential variation ranging from approximately ground potential to near the anode potential is established within the plasma due to the interaction of electrons with the magnetic field.

This description is summarized. For more information, refer to the literature in the reference 1 in the Reference section.

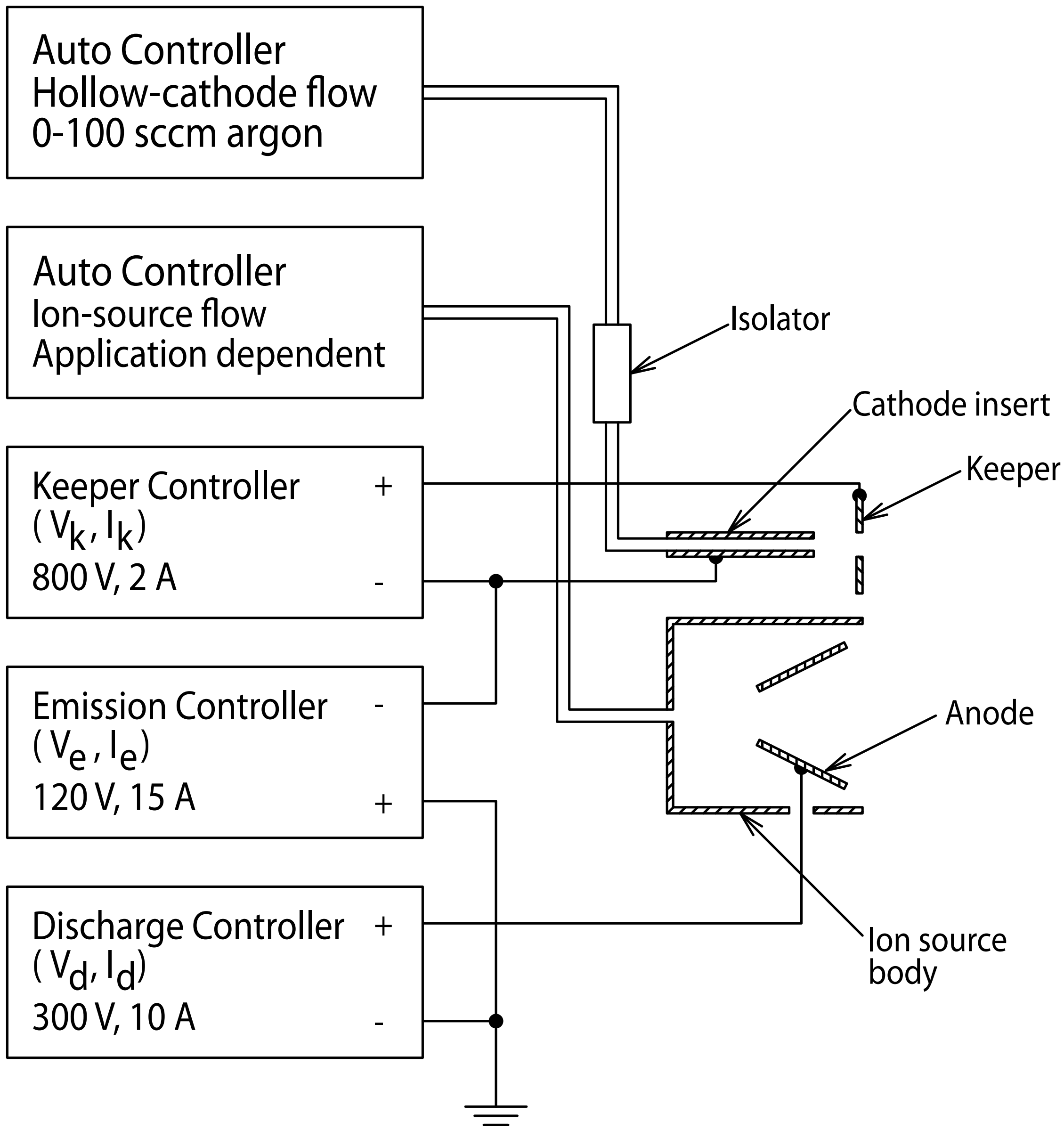

Figure 4-1. Schematic diagram of the eH2000HC ion source and power supplies.

5. OPERATION

Operation of the eH2000HC ion source can be accomplished with the use of the following information. Operating parameters for the ion source can be found in Chapter 6 of this manual. Additional information can be found in Section 3 of this manual to assist with the application of the ion source. Prior to operating the eH-2000HC ion source, review all of the details outlined in the Chapter 2 of this manual and the Installation section for the eH2000HC Controller to insure that correct installation has been done, and all procedures have been followed. This chapter assumes that the operator has completed the initial setup procedures outlined in any accompanying controllers and is familiar with each controller's operation.

5.1 Hollow Cathode Neutralizer

Prior to starting the electron source an argon gas flow of 100 sccm (standard cubic centimeters per minute) should be established into the electron source. If the electron source has not been operated previously or if the cathode has been at atmosphere with no argon flow through the cathode, the gas flow should be maintained at this gas flow for 15 minutes prior to starting. This flow time is intended to allow the cathode to thoroughly outgas thus preventing premature failure of the cathode due to contamination.

Note: If the electron source has been exposed to atmosphere and a flow of argon gas was maintained at 10 sccm through the cathode during its exposure only a few minutes of flow time is required prior to staring the cathode, after the vacuum facility has reached a normal base pressure for that system.

- Select Gas 4 using the white Gas Channel Select button on the Auto Controller and then turn the Gas Adjust knob to 10 sccm.
- Press the white Enable/Standby button on the Auto Controller. Gas should be allowed to flow through the hollow cathode for 15 minutes at 10 sccm (as previously stated) before proceeding to the next step.
- 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 Setpoint Adjust knob on the Keeper Controller until 1.5 amps is indicated in the Keeper Amps display.
- Turn the Setpoint Adjust knob on the Emission Controller until 2.7 amps

is indicated in the Emission Amps display. Take note that the emission current in amps is usually set equal to or up to 10% greater than the discharge current.

- Press the white Enable/Standby button on the Keeper Controller 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 gas flow on Gas 4 to 10 sccm.
- Press the white Enable/Standby button on the Emission Controller.
- The hollow cathode should now be running on its own.

5.2 Starting the eH2000HC Ion Source

- Turn on the water supply to the anode.
- Select Gas 1 using the white Gas Channel Select button on the Auto Controller and then turn the Adjust knob to 20 sccm.
- Use the white Amps/Volts Select buton on the Discharge Controller to select Volts. Turn the Setpoint Adjust knob on the Discharge Controller until the discharge voltage is set to maximum as indicated on the Discharge Volts display.
- Use the white Amps/Volts Select button on the Discharge Controller to select Amps. Turn the Setpoint Adjust knob on the Discharge Controller 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 Discharge Controller.
- Adjust the gas flow for Gas 1 using the Gas Adjust knob on the Auto Controller until the Discharge Volts display reads approximately 120 volts.
- 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 on Gas 1 after 10 minutes to obtain a discharge voltage of approximately 120 volts.

- Stop operation by putting the discharge, emission, keeper, and gas flow into Standby in that order by pressing the white Enable/Standby button on each controller.

5.3 Adjustments

Once the electron source and ion source are operating, slight adjustments may be needed to achieve the desired operating conditions. For more information on adjustments and different modes, see the Operation Section of the KRI® Auto Controller manual.

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6. CHARACTERISTICS

This chapter includes typical performance characteristics for a KRI® eH2000HC water-cooled anode ion source while using a hollow cathode neutralizer. The data provided should be used as a guide for operating parameters of the ion source.

6.1 Hollow Cathode Electron Source

The hollow cathode electron source can operate up to 10 amps of emission current. A flow of 10 sccm of argon is recommended for optimum lifetime of the electron source. With properly cleaned gas lines, uncontaminated gas, and 10 sccm of argon flow the electron source can operate hundreds of hours when using inert gas. With reactive gas for the ion source, the life time will be reduced. Refer to the Inspection and Installation Section 2 for proper gas procedures. The electron source will operate at lower gas flows if necessary, but it will limit the lifetime of the cathode tip. Figure 6-1 illustrates the keeper voltage as a function of argon flow to the electron source.

6.2 Discharge Voltage

The eH2000HC can operate at a range of discharge voltages from 40 to 300 volts with up to 10A of discharge current, and a maximum power limit of 1700 watts of discharge power. The ion source must not be operated above 1700 watts to avoid damaging the magnet and magnetic field. Table 6-1 illustrates the maximum voltage for a given current.

Table 6-1. Maximum discharge voltage.

V_d, volts	I_d, amps
300	2.5
300	5.0
226	7.5
170	10.0

Figure 6-2 illustrates the range of operation for the ion source, at four different pump speeds. The two foremost curves illustrate a reduced operating range for the discharge voltage, this is due to the lower pumping speeds. At the higher pump speeds (1100 and 1600 l/s), the higher discharge voltage range is not limited by pump speed, but rather the power limit of the ion source at 2.5 and 5 A.

The ion source will require more gas flow for a given discharge voltage and current at higher pump speeds. The foremost curve with a vacuum facility pump speed of 500 l/s (pink) illustrates the required gas flow for a given discharge voltage of 75 V and a discharge current of 2.5 A is approximately 18 sccm of argon. At a high pump speed of 1700 l/s, the curve (green) shows that the ion source will now require about 20 sccm of argon to obtain the same 75 V and 2.5 A of discharge.

The type of gas will also affect the discharge voltage. The required gas flow will decrease as the atomic or molecular weight of the working gas increases. Figures 6-3 and 6-4 show the range of operation of the ion source using oxygen and nitrogen for a range of pump speeds. This data was taken using a 10 in. (25 cm) cyropump.

6.3 Vacuum Facility Pump Speed

It may be necessary to calculate the pump speed for a particular vacuum facility. The pump speed is typically not the rated value of the vacuum pump. If the pump is not directly connected to the vacuum chamber, if there are flanges that restrict the open area to the pump, any distance or angle will reduce the effective pumping speed of the vacuum facility. For more information on pumping reduction due to a decrease in open area and distance, refer to reference 1 for causing factors. Using the universal gas law, a simple calculation for pump speed is:

$$S = F(1.27 \times 10^{-2})/P_{chamber}$$

Where S is the pump speed in l/s, F is the gas flow in sccm and Pchamber is the chamber pressure in Torr at the specific gas flow. Note that pressure measurement is assumed to be corrected for the specific gas used. This calculation assumes that only one type of gas is used, if multiple gases are used, the effective pump speed will be less.

In order to compare the vacuum pump speed of the users vacuum facility to the pump speeds shown in Figures 6-1 through 6-4, the user should set the gas flow to 20 sccm and record the vacuum chamber pressure. This pressure and flow can be used in the formula previously mentioned, for comparison purposes.

6.4 Ion Beam Current and Energy

The ion beam current and energy for the KRI® eH2000HC ion source is shown in Figures 6-5 through 6-9. These measurements were taken with extensive ion beam probe surveys and are not directly available from the ion source controller. These values should be used as a guide to what may be expected. Complicated calculations and corrections are necessary for any probe survey. If a probe survey is required to obtain a more exact value of the ion beam current or energy, refer to reference 1 for more information.

The ion beam current is proportional and approximately 25% of the discharge current over most of the discharge voltage range. These values are plotted in Figures 6-5 through 6-7 against discharge voltage for various discharge currents and several gases. Note that the discharge voltage is the voltage applied to the anode of the ion source. At low discharge voltages, the beam current decreases. The low voltage operation of the ion source require high gas flows and for small decreases in the discharge voltage, a large increase in gas flow is necessary.

Figure 6-8 shows the mean ion energy plotted against discharge voltage. The mean ion energy is proportional to the discharge voltage and is typically about 65% of the discharge voltage. For example, with a discharge voltage of 100 V, the mean ion energy would be about 65 eV. Less gas flow results in fewer collisions of the electrons in the discharge region, which for the same discharge current results in a stronger electric field and higher ion energy. Higher gas flows will consequently have less ion energy.

Figure 6-9 is a sample retarding potential probe analysis curve on axis of the ion source. The mean energy shown in Figure 6-8 was obtained from curves similar to this. An electric field is associated with the interaction of the plasma (sheath) and the magnetic field. This will cause probe currents to be measured at voltages above the discharge voltage. Probe currents can also be found less than zero, due to small leakage of electrons to the collector of the probe.

6.5 Ion Beam Profiles

The ion beam profiles in this section were taken using a screened probe that excludes electrons and measures only ions. Refer to Reference 1 for more information. Spherical target profiles with the source at the center of the sphere and flat target profiles that are normal to the beam axis are included at a working distance of 30 cm (12 in.). Figure 6-10 illustrates both target configurations. Argon profiles can be found in Figures 6-11 through 6-16. Oxygen and nitrogen profiles are included in Figures 6-17 through 6-28. The ion current density would vary inversely as the square of the distance at other target distances.

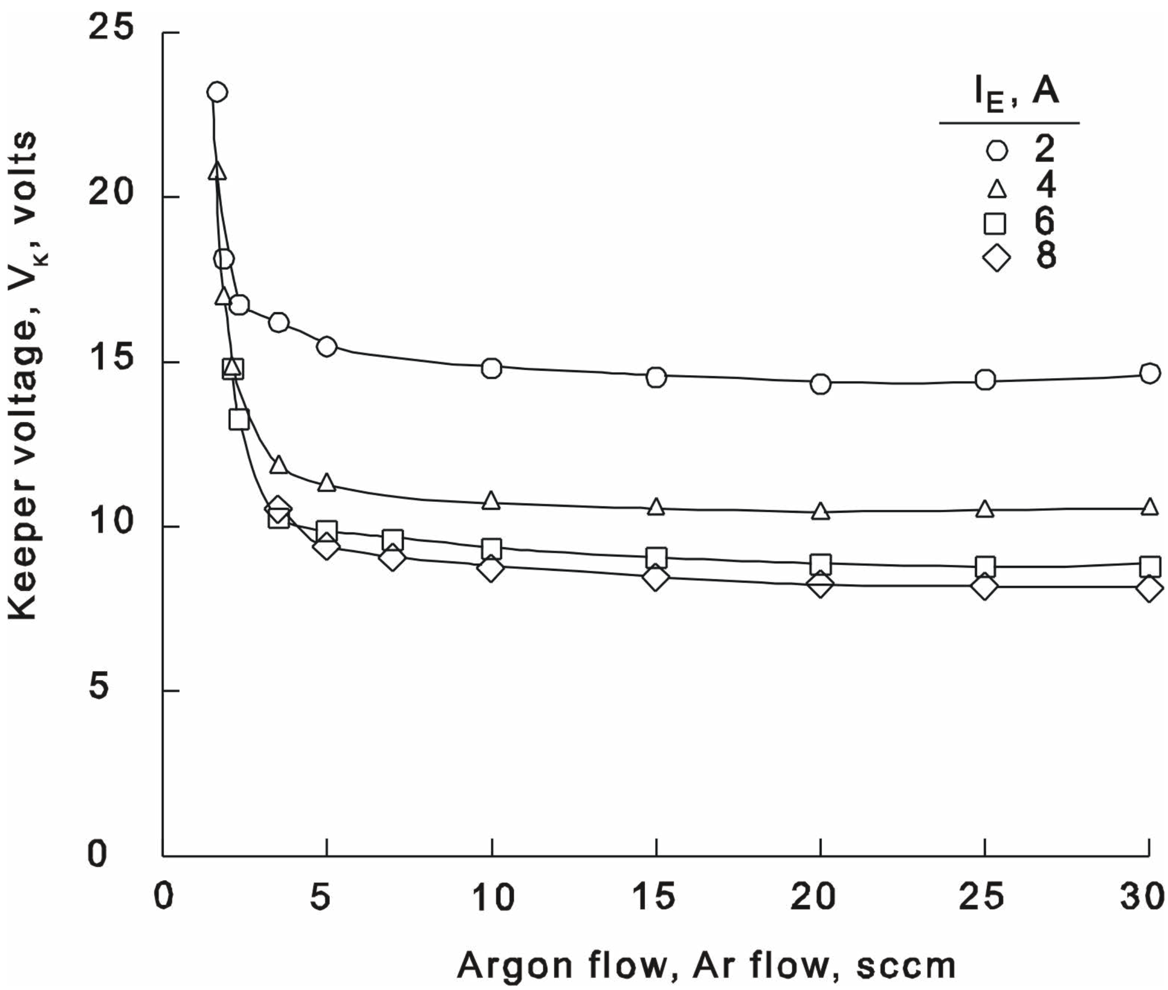

Figure 6-1. Variation in hollow cathode keeper voltage with argon gas flow for various emission currents.

CHARACTERISTICS 6-5

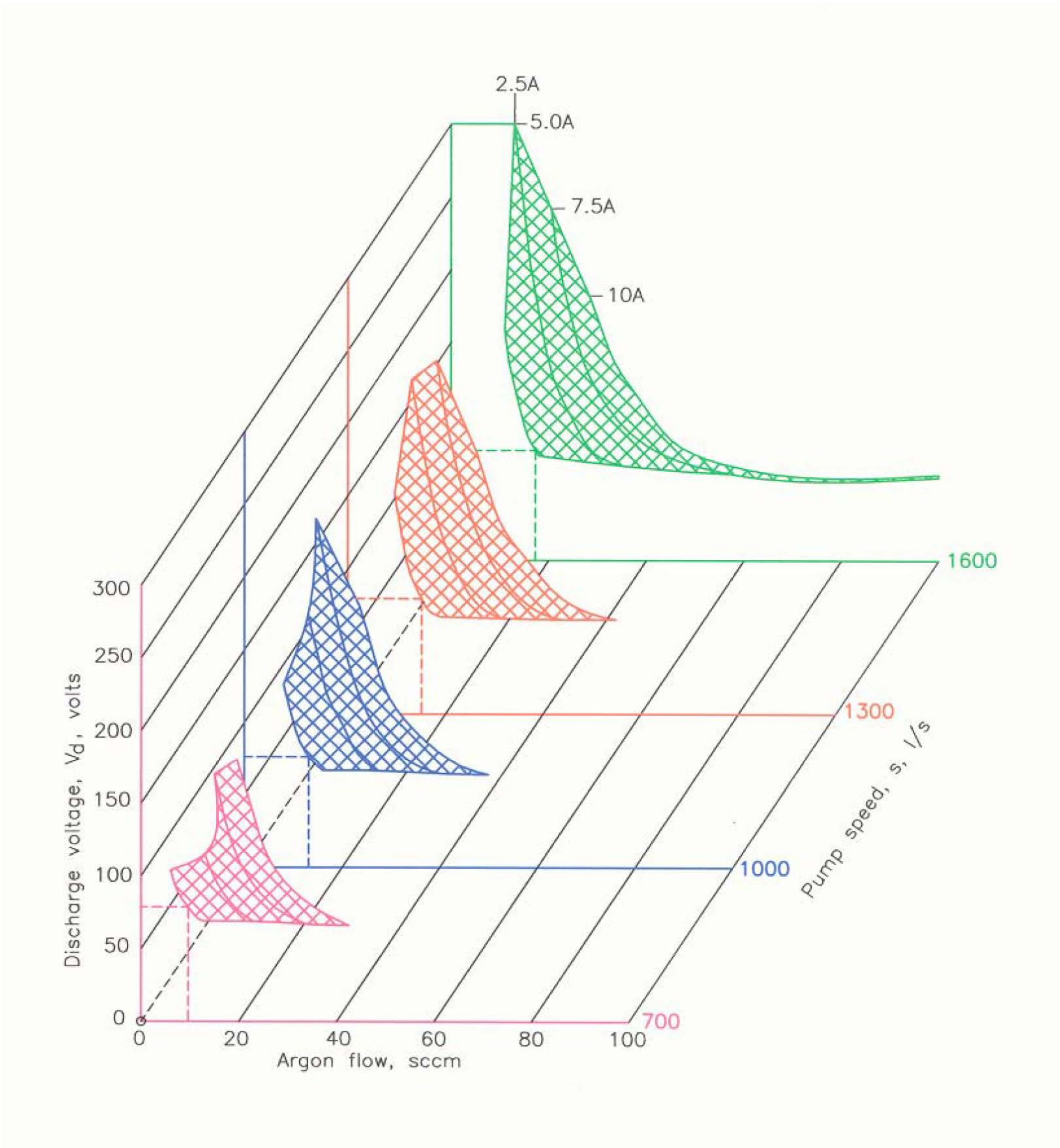

Figure 6-2. Range of operation for the KRI® eH2000HC ion source at various pump speeds, using argon.

6-6 CHARACTERISTICS

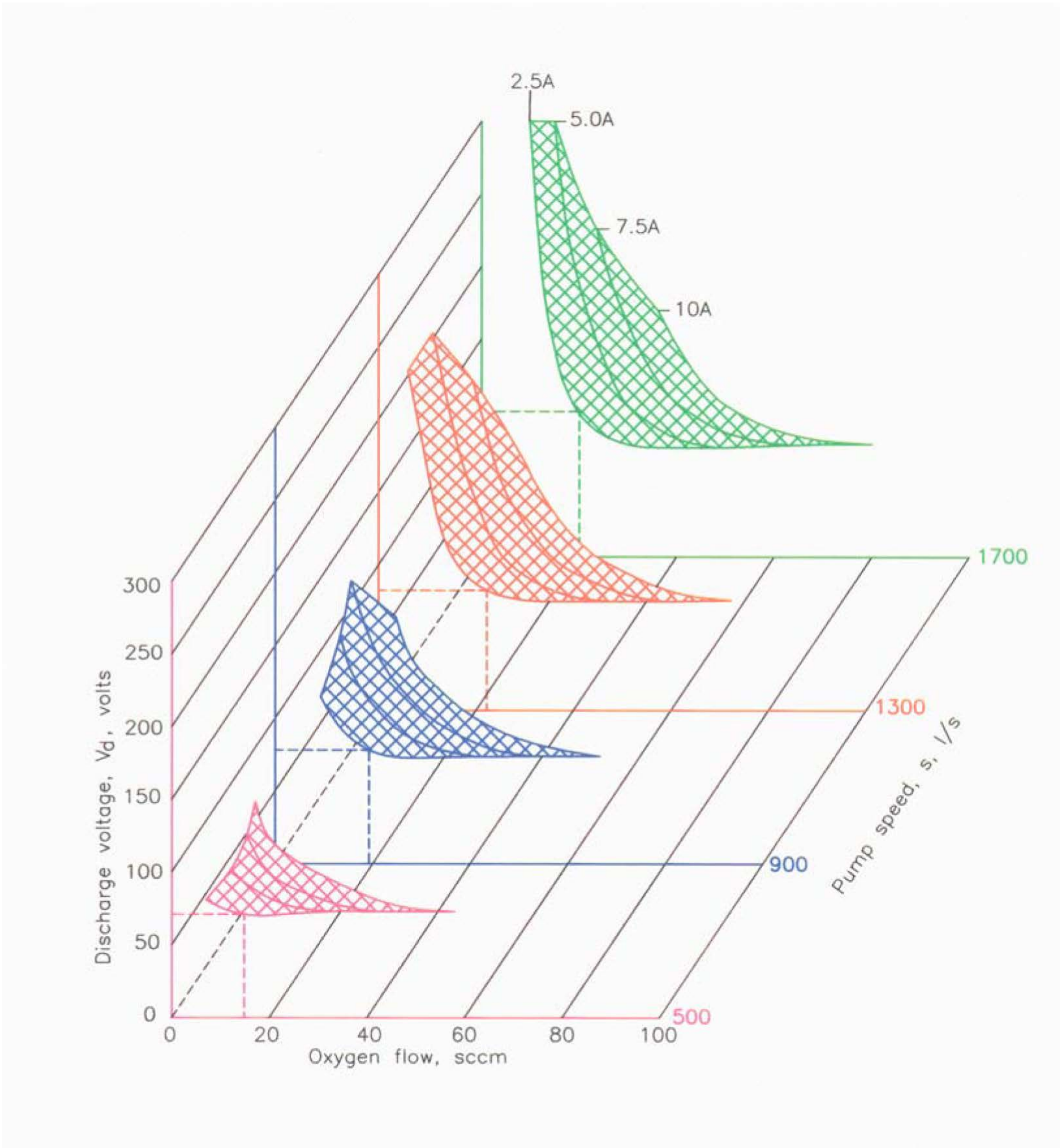

Figure 6-3. Range of operation for the KRI® eH2000HC ion source at various pump speeds, using oxygen.

CHARACTERISTICS 6-7

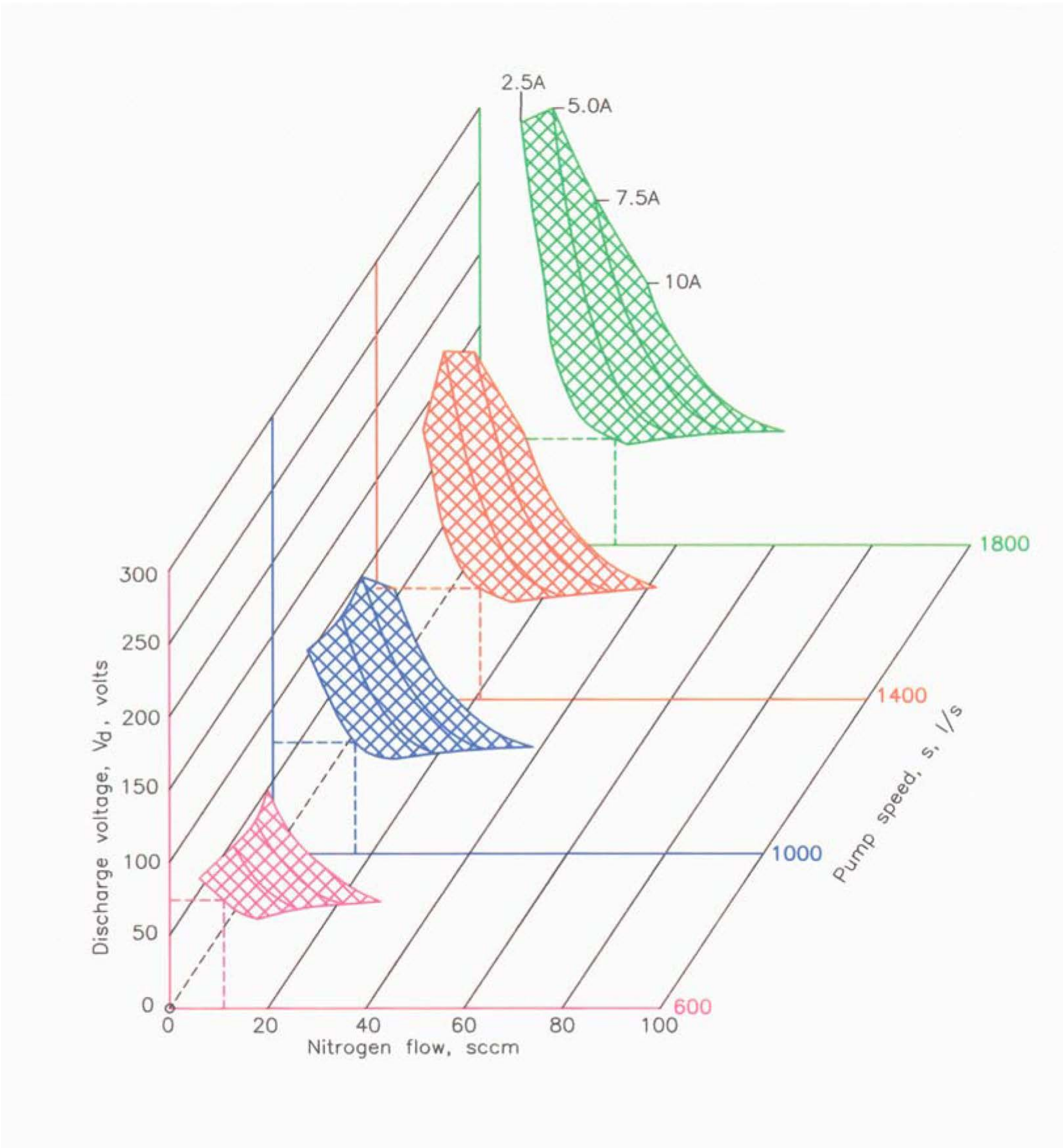

Figure 6-4. Range of operation for the KRI® eH2000HC ion source at various pump speeds, using nitrogen.

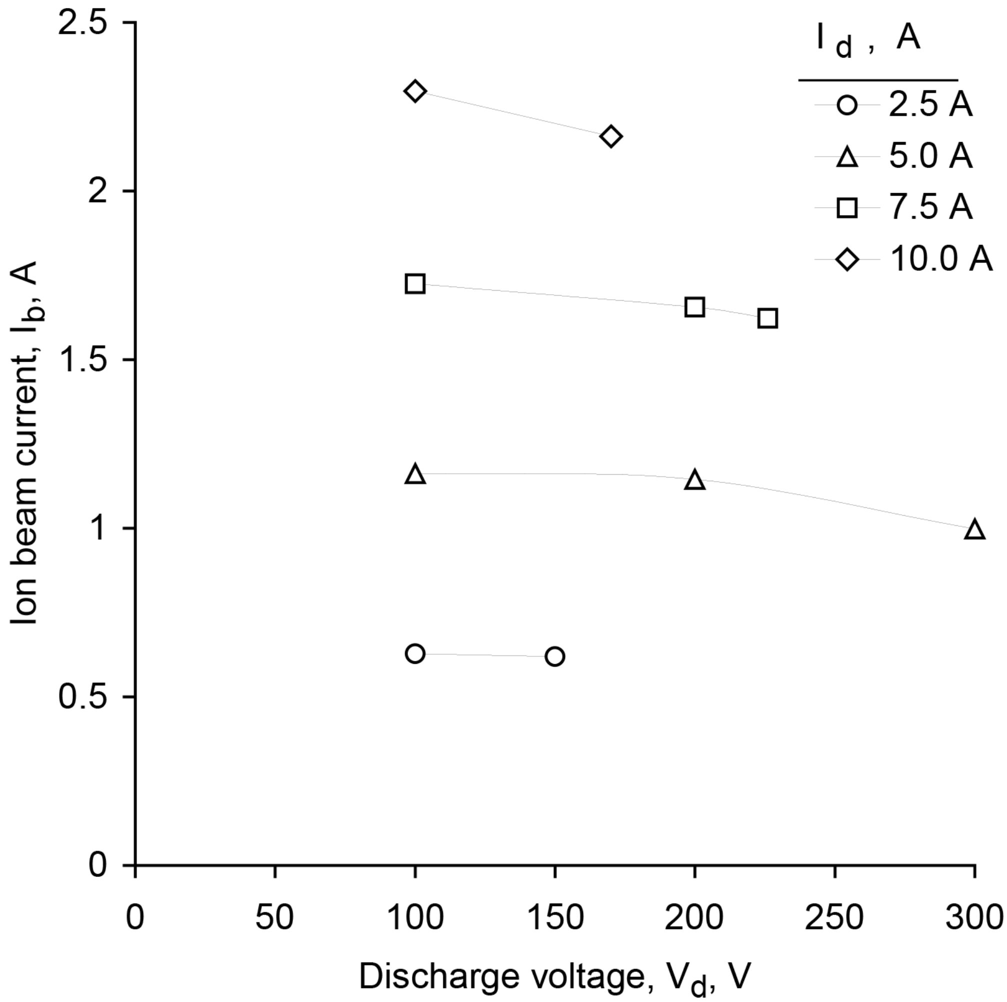

Figure 6-5. Variation of ion beam current with discharge voltage at various discharge currents, using argon.

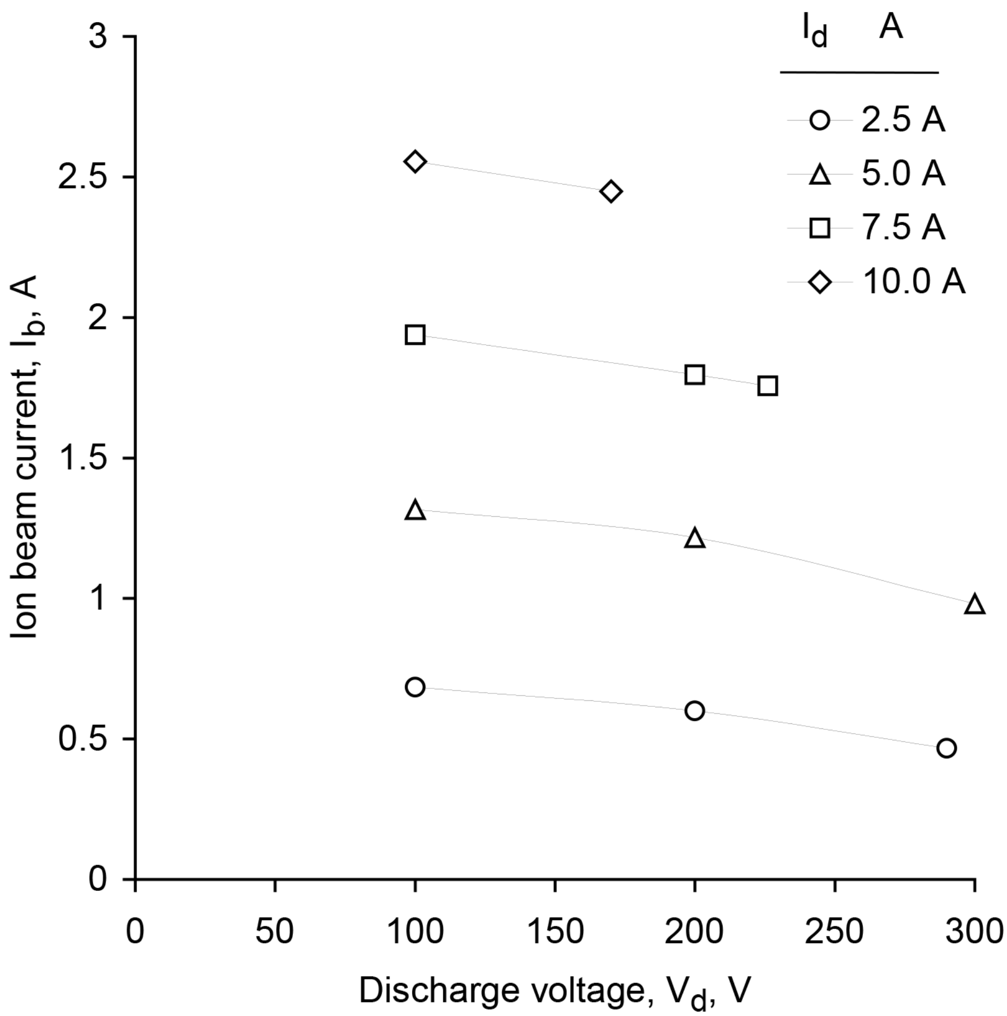

Figure 6-6. Variation of ion beam current with discharge voltage at various discharge currents, using oxygen.

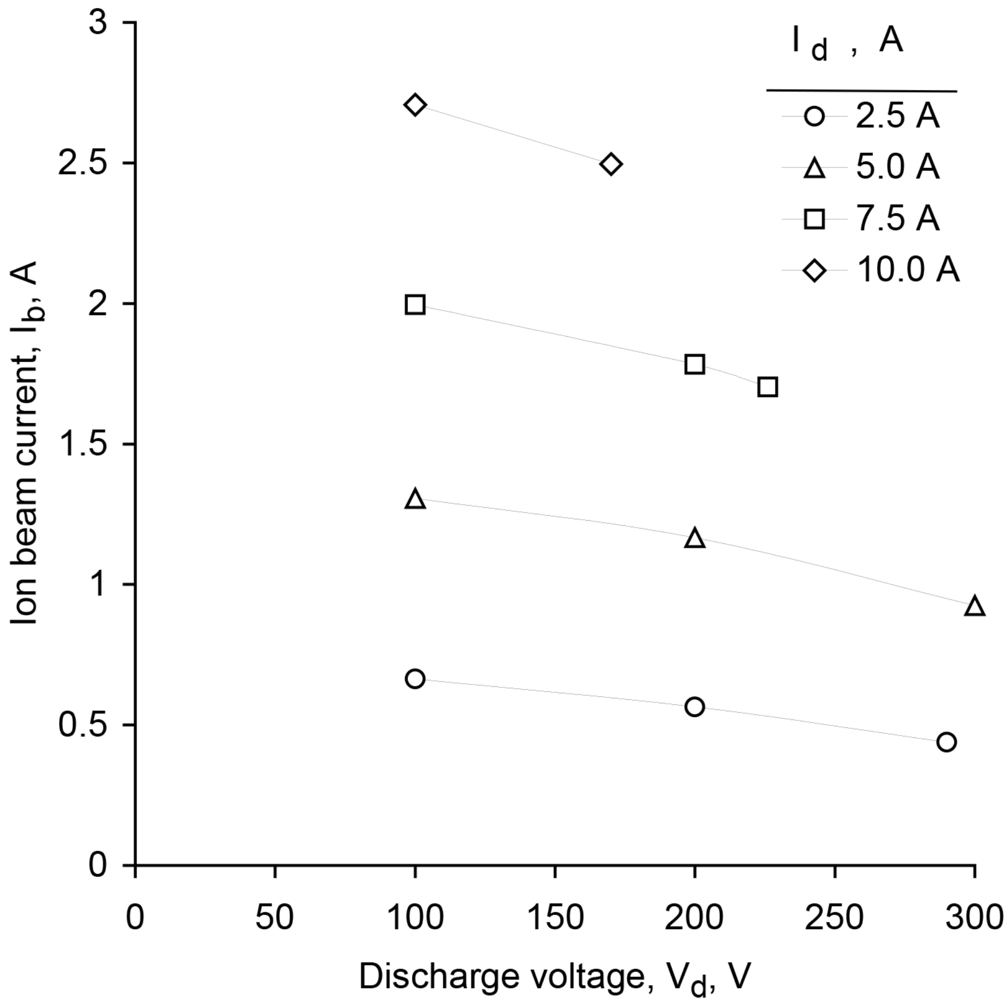

Figure 6-7. Variation of ion beam current with discharge voltage at various discharge currents, using nitrogen.

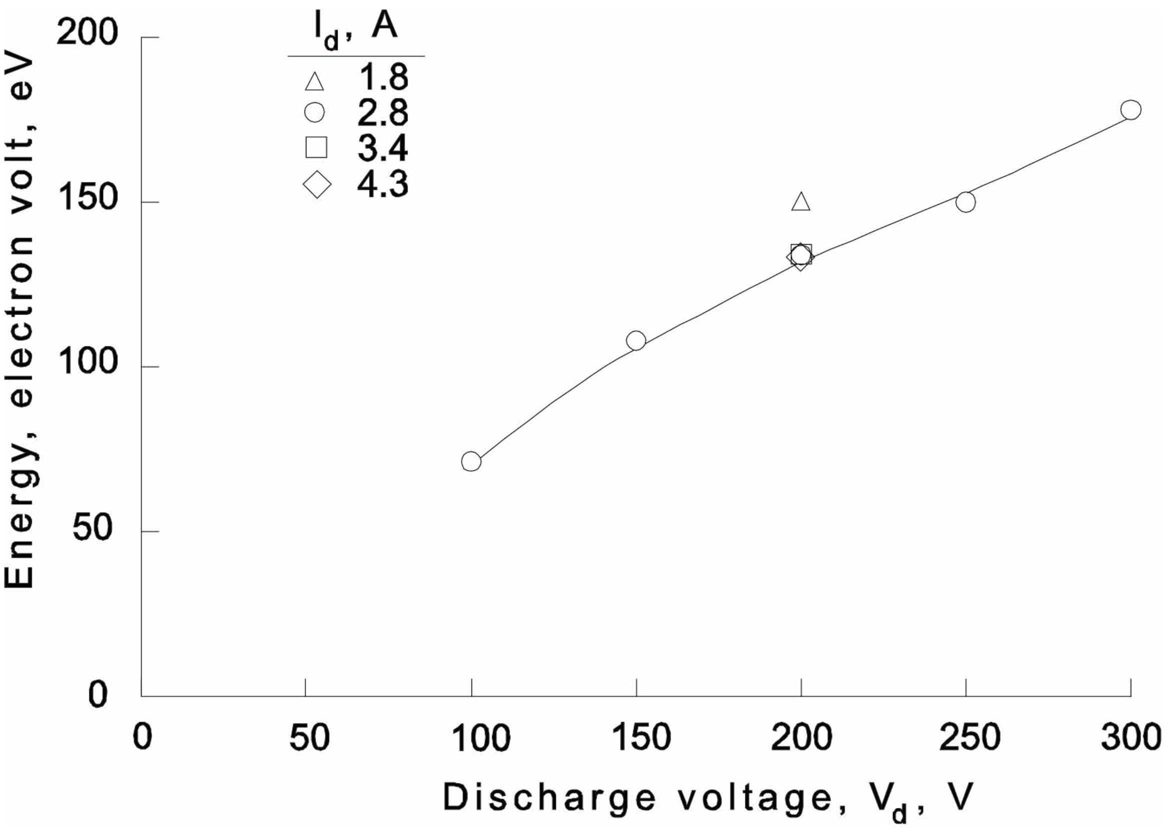

Figure 6-8. Mean ion energy with variation in discharge voltage.

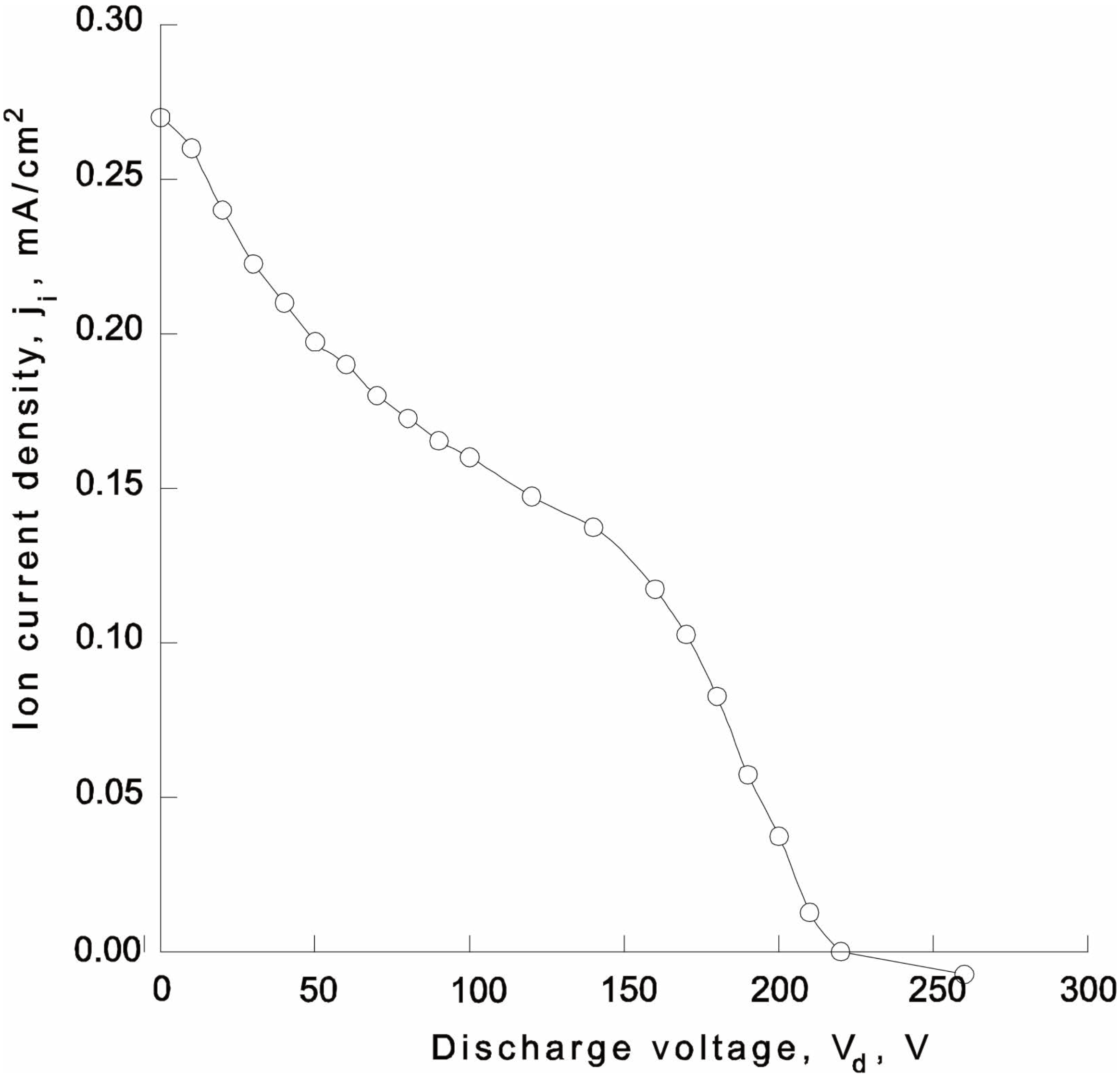

Figure 6-9. Retarding potential probe analysis of the ion beam at a discharge voltage and current of 200 V and 2.8 A.

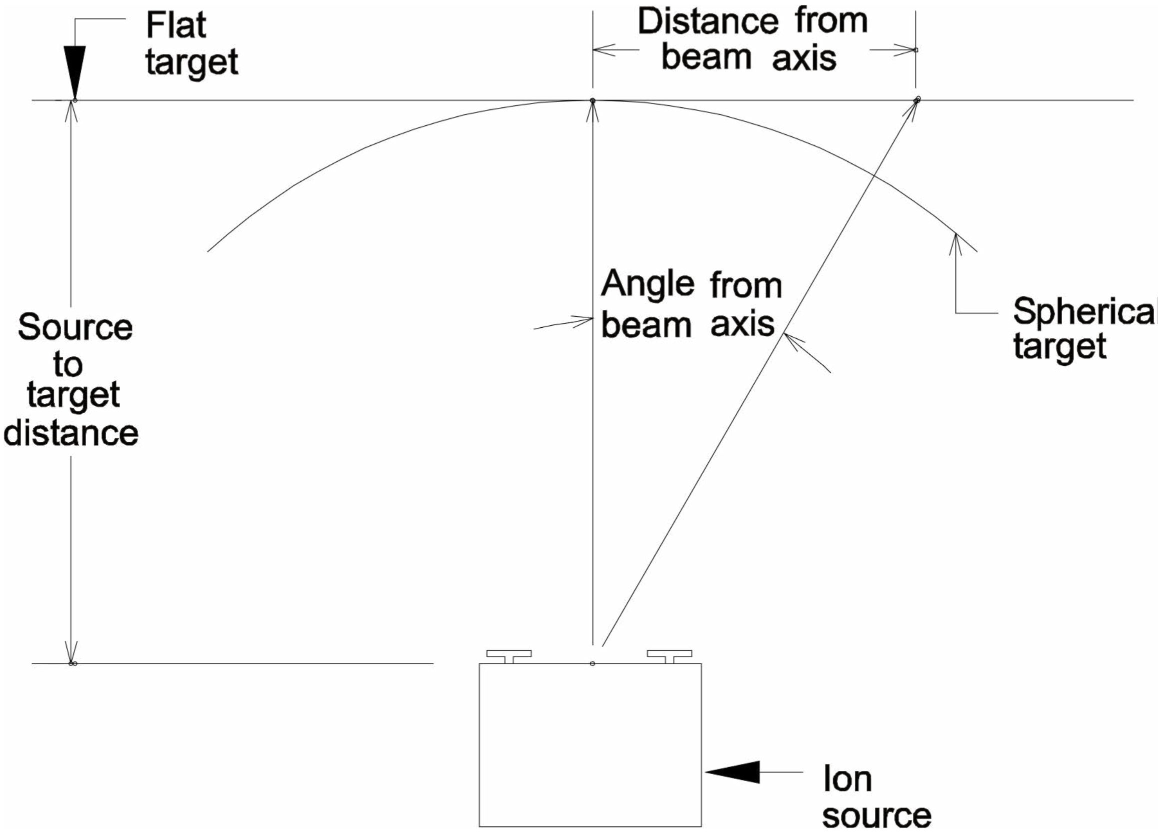

Figure 6-10. Spherical and flat target configurations.

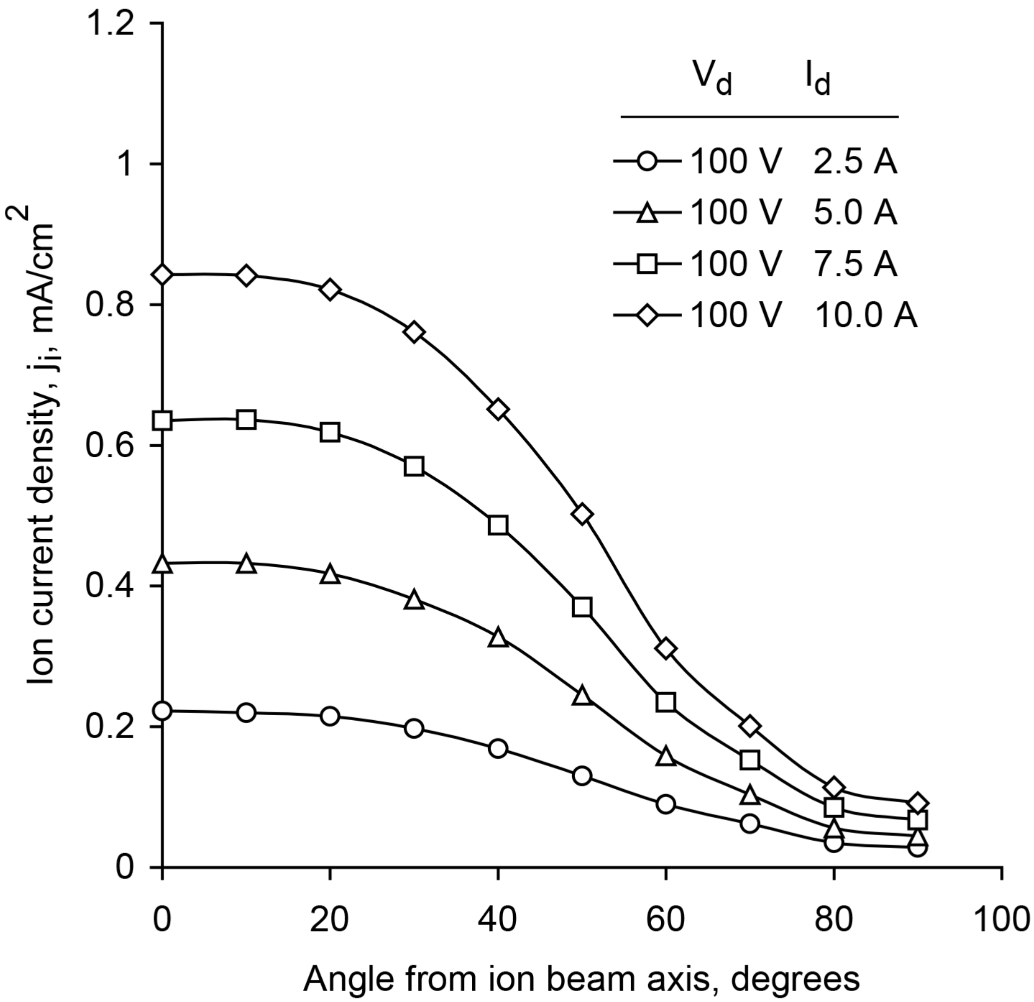

Figure 6-11. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

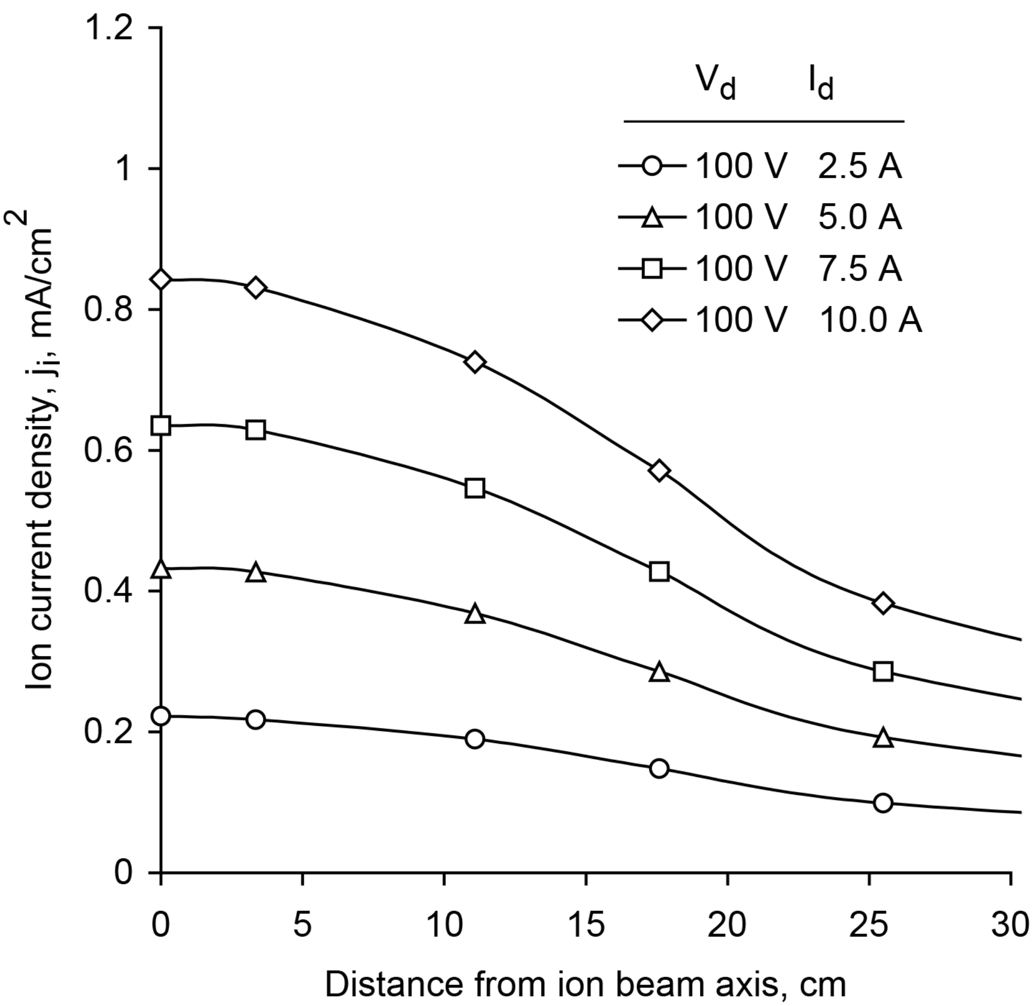

Figure 6-12. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon.

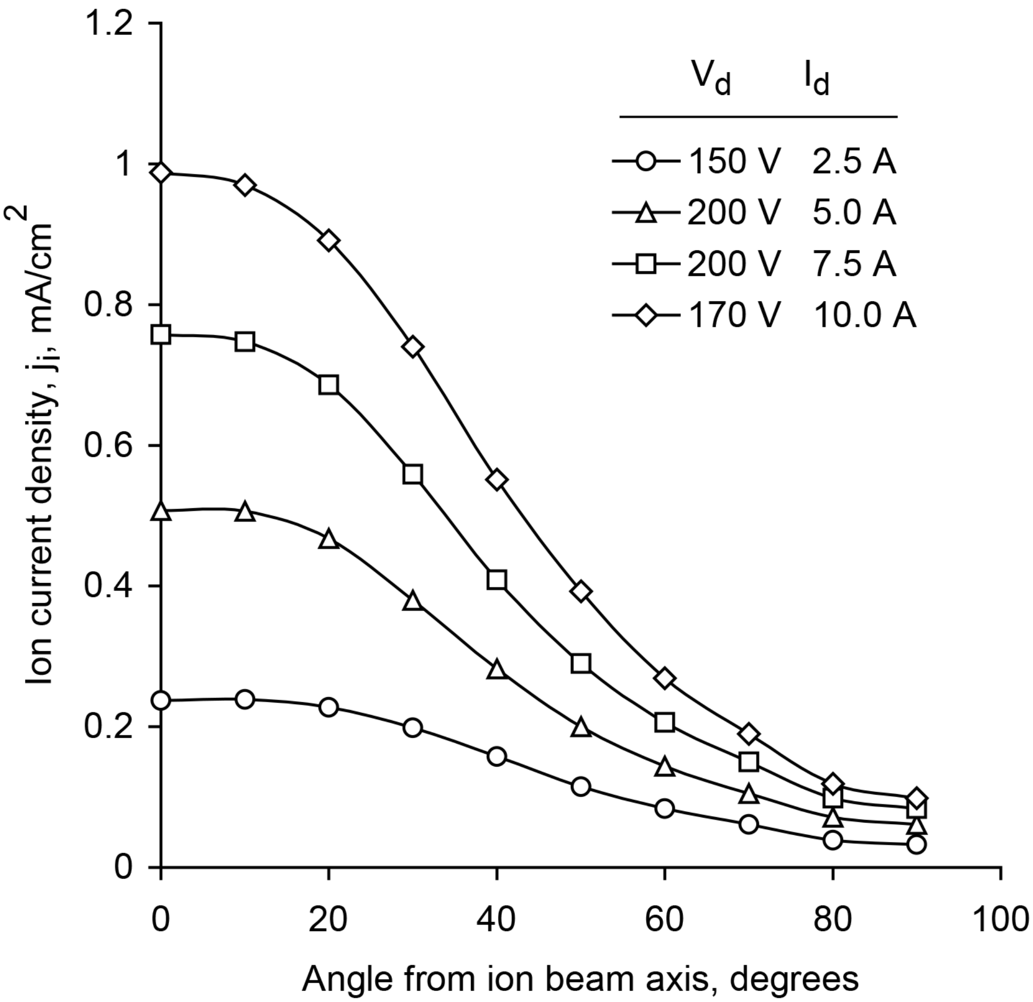

Figure 6-13. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

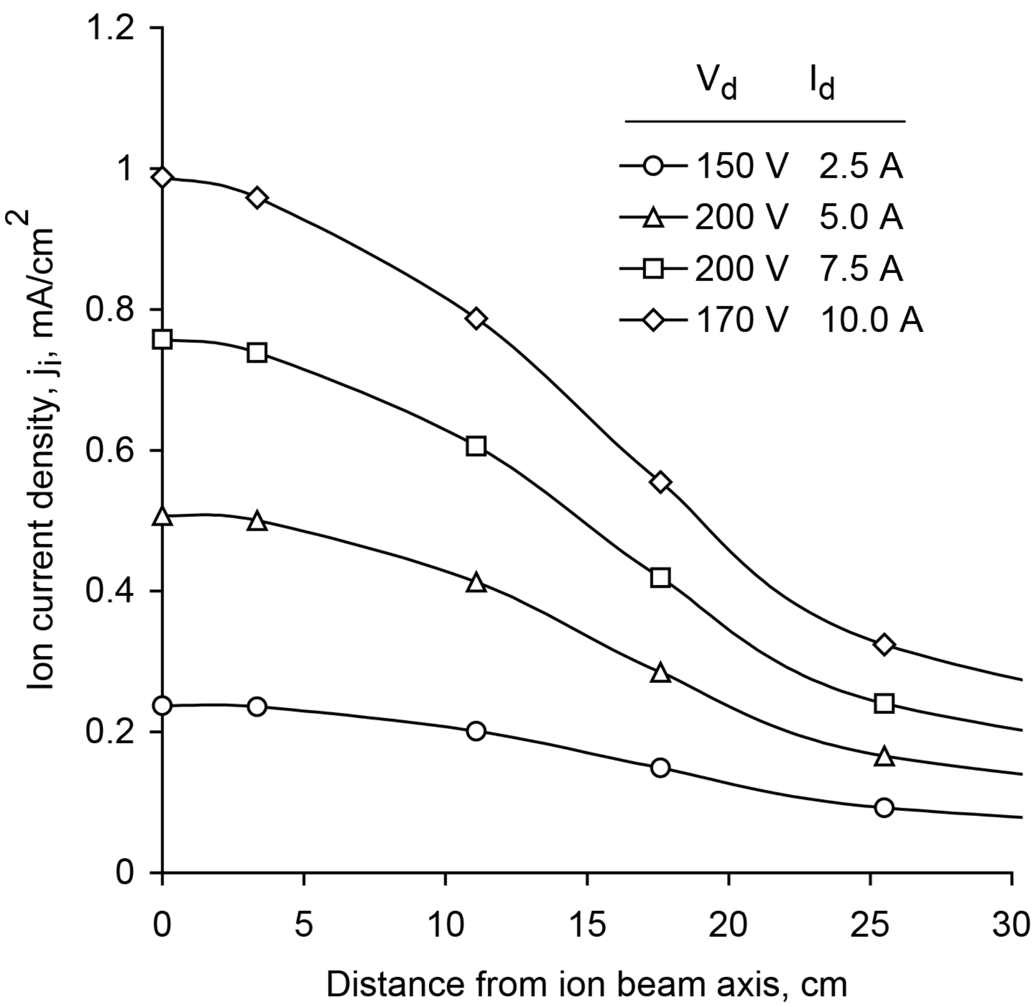

Figure 6-14. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon.

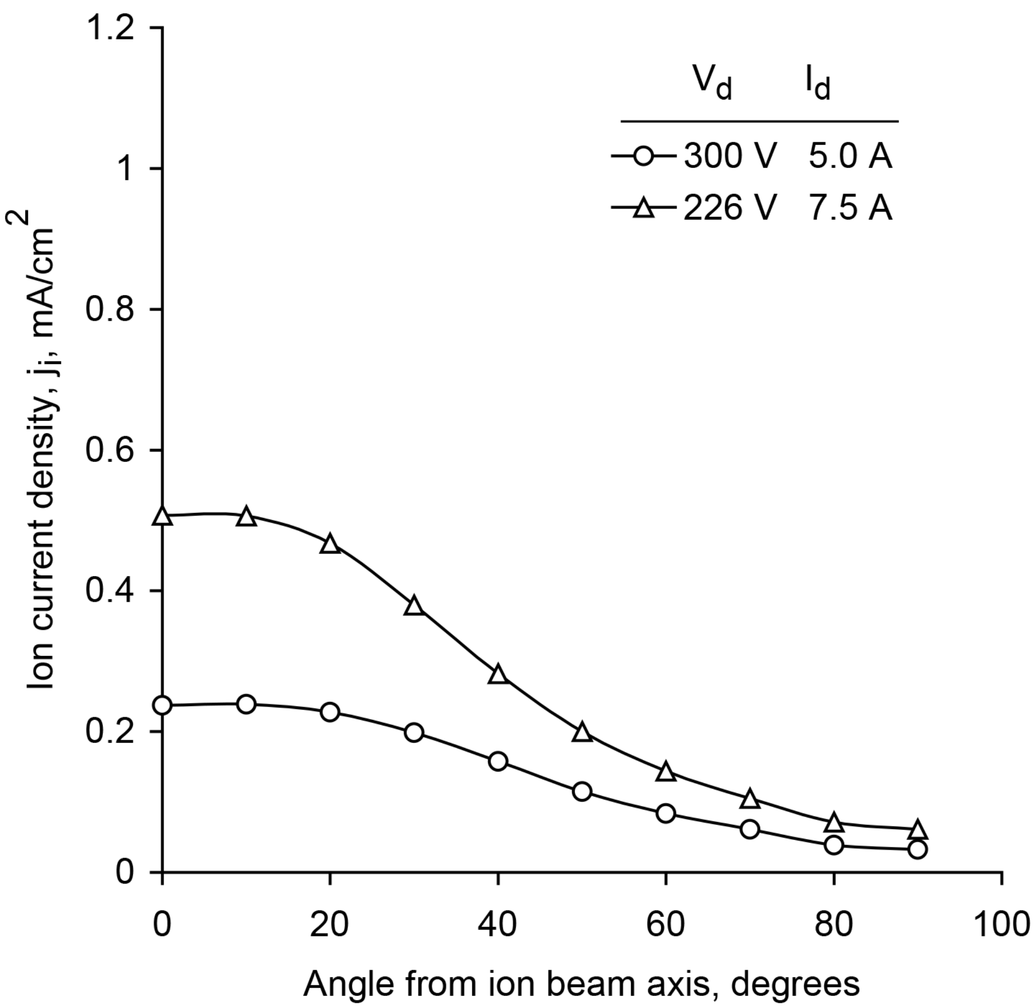

Figure 6-15. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

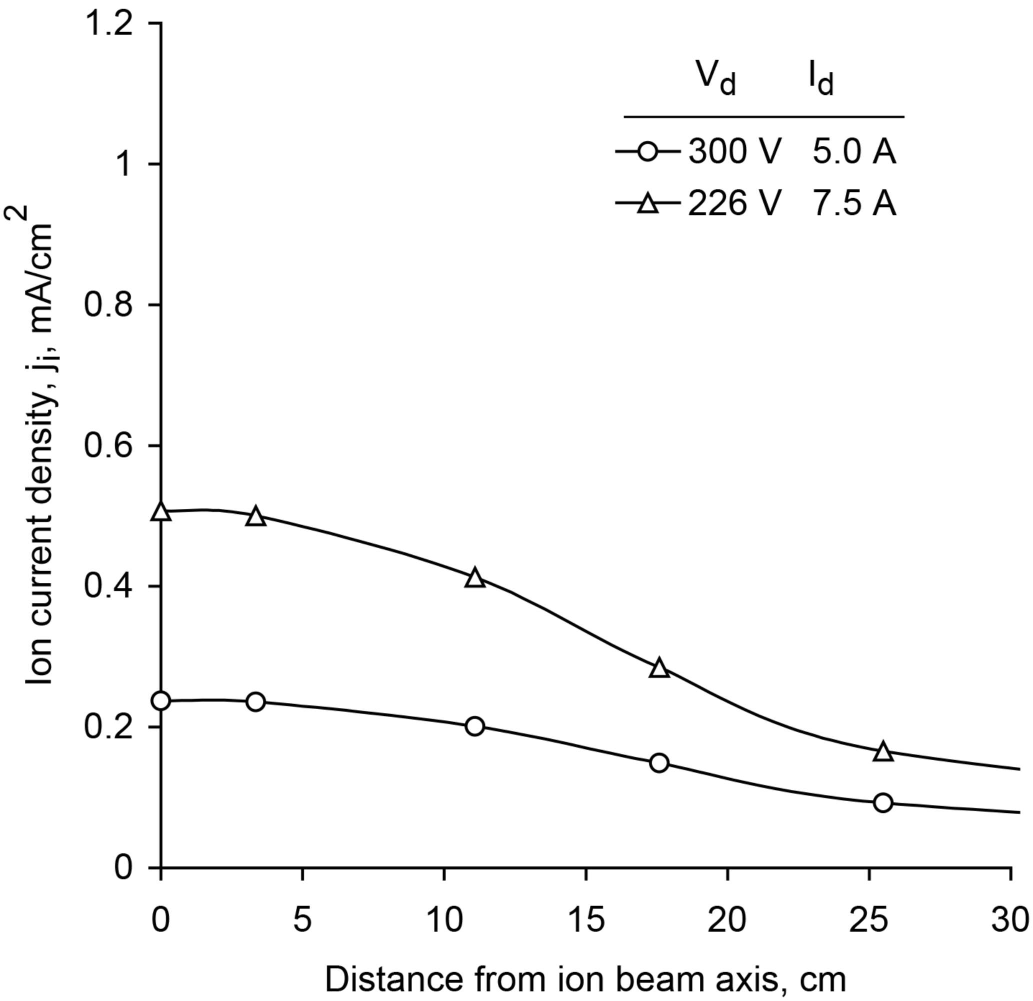

Figure 6-16. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon.

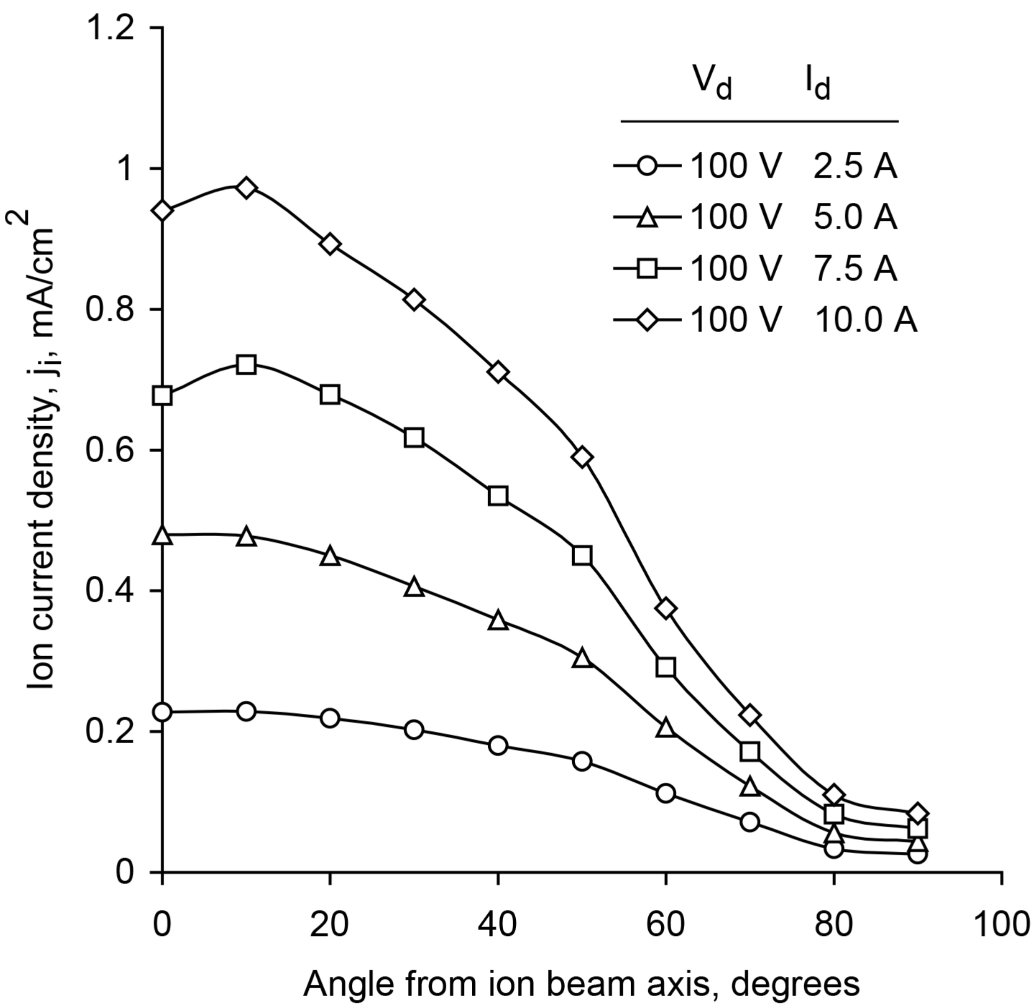

Figure 6-17. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

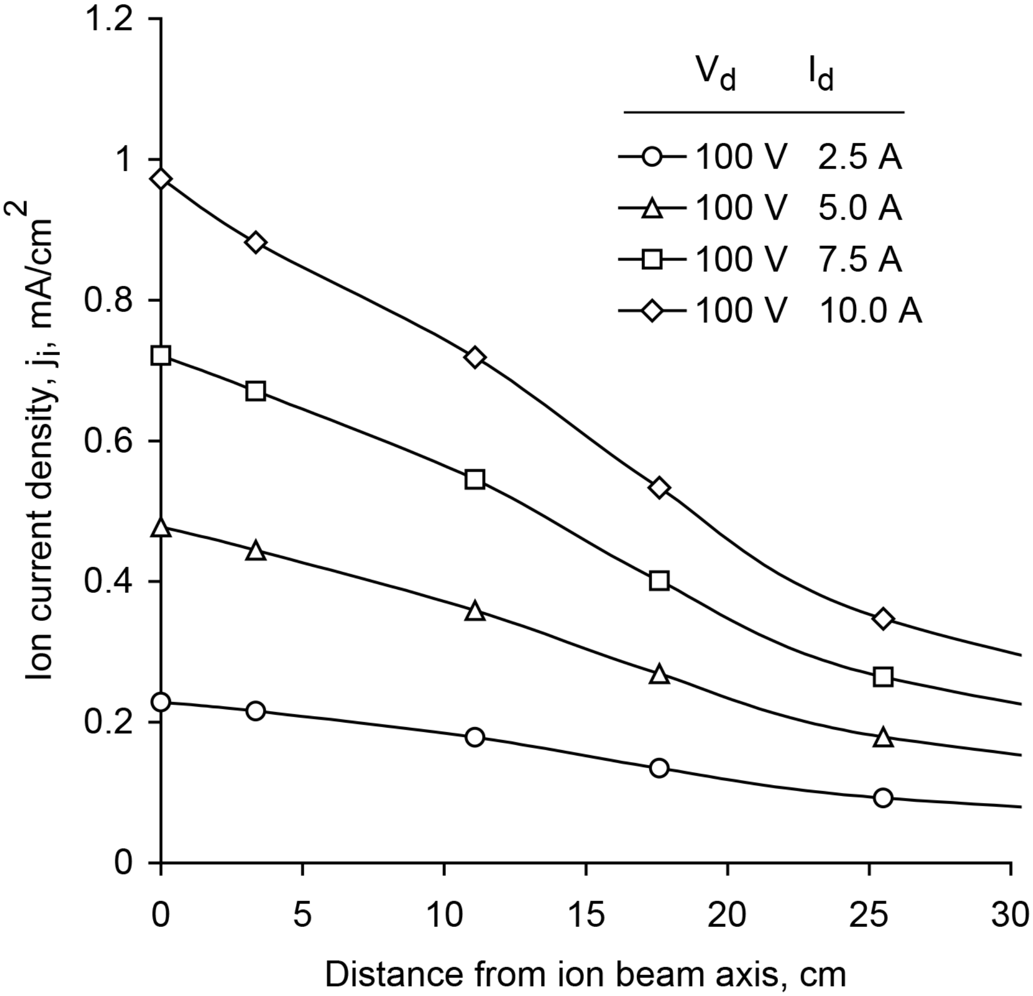

Figure 6-18. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

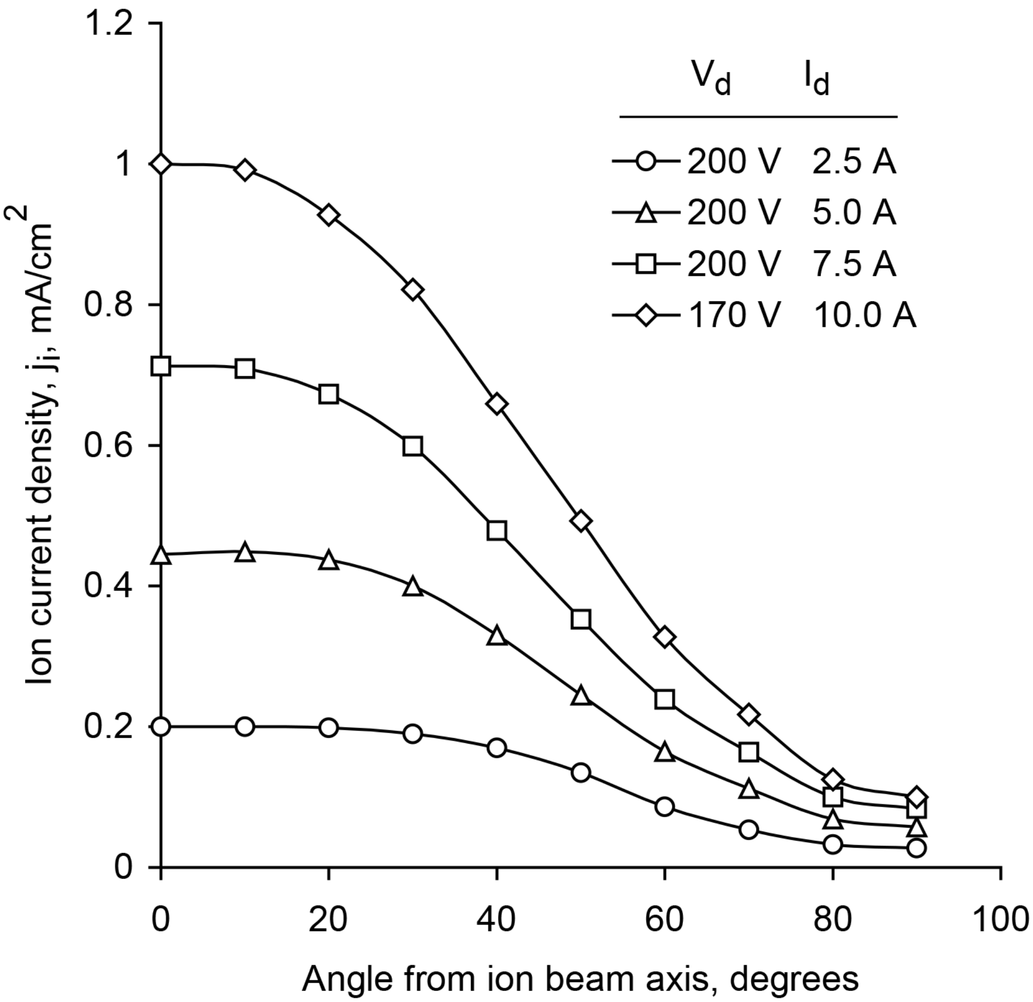

Figure 6-19. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

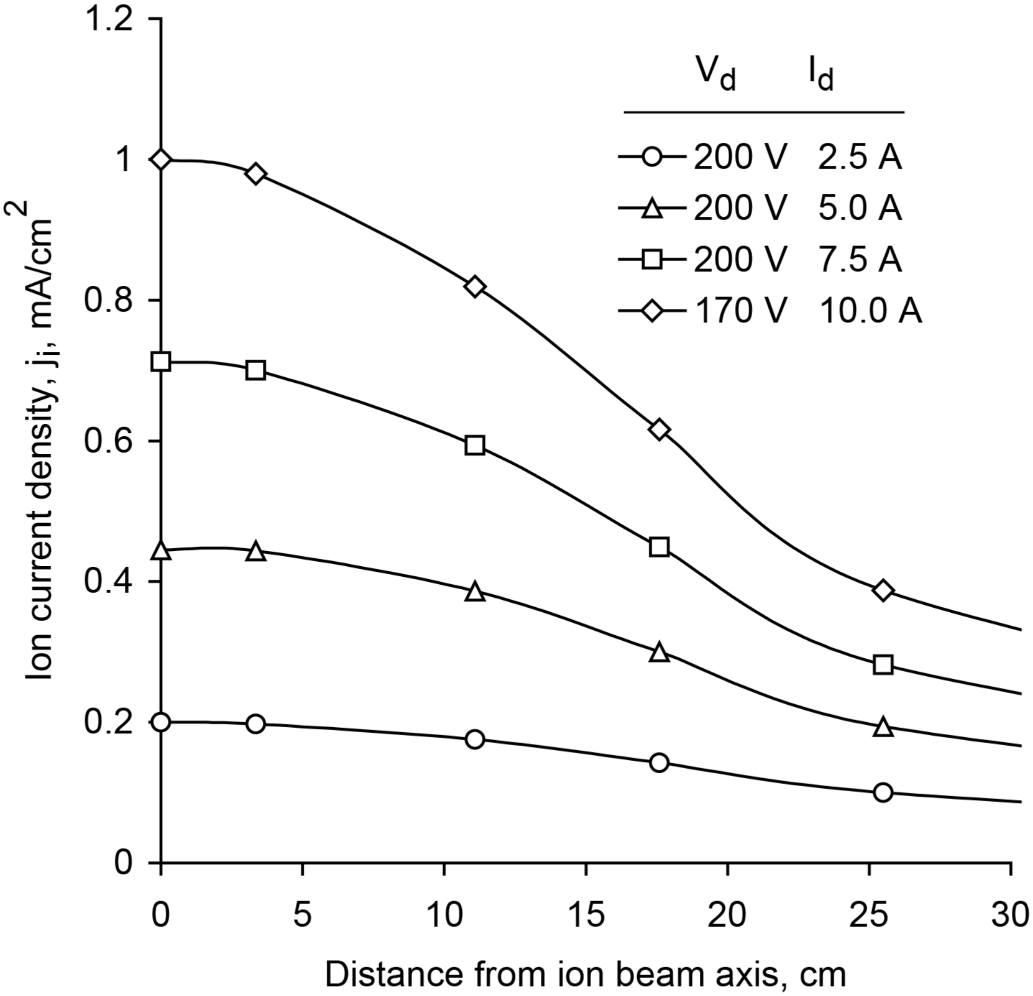

Figure 6-20. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

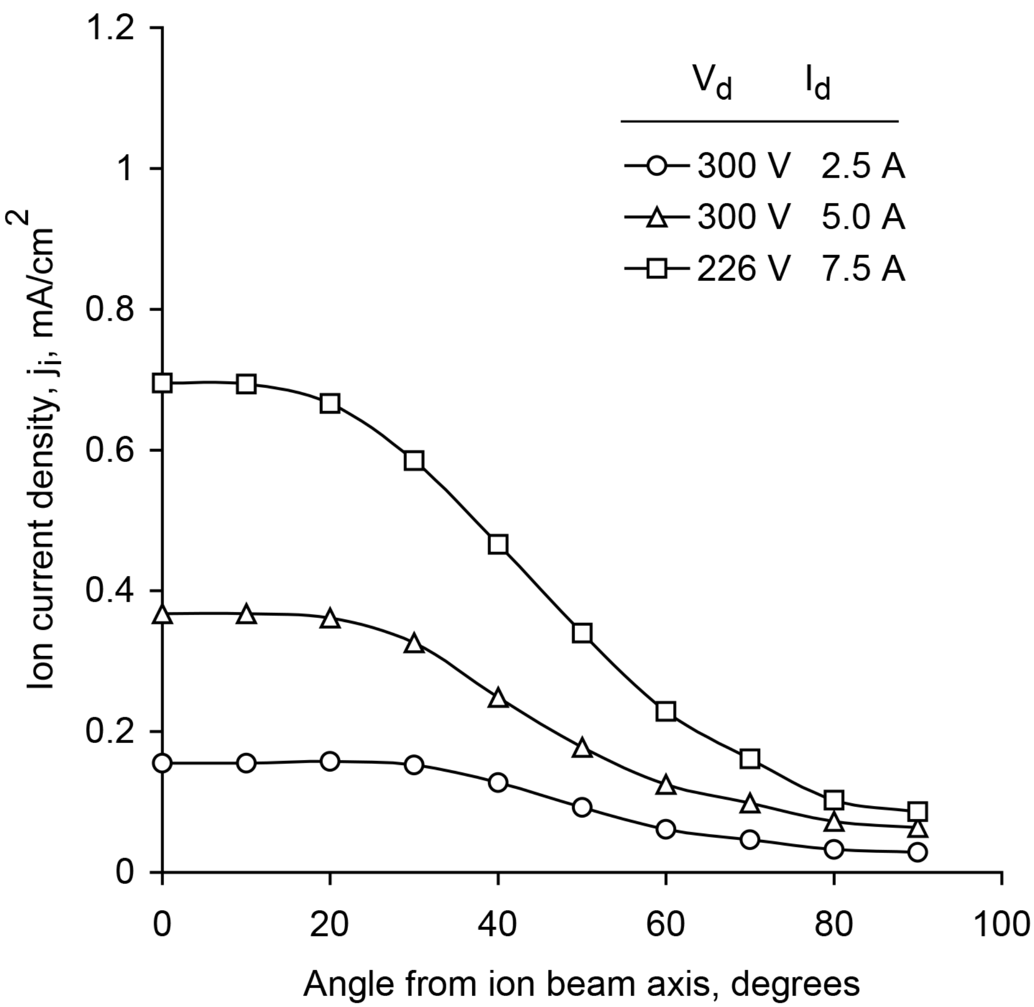

Figure 6-21. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

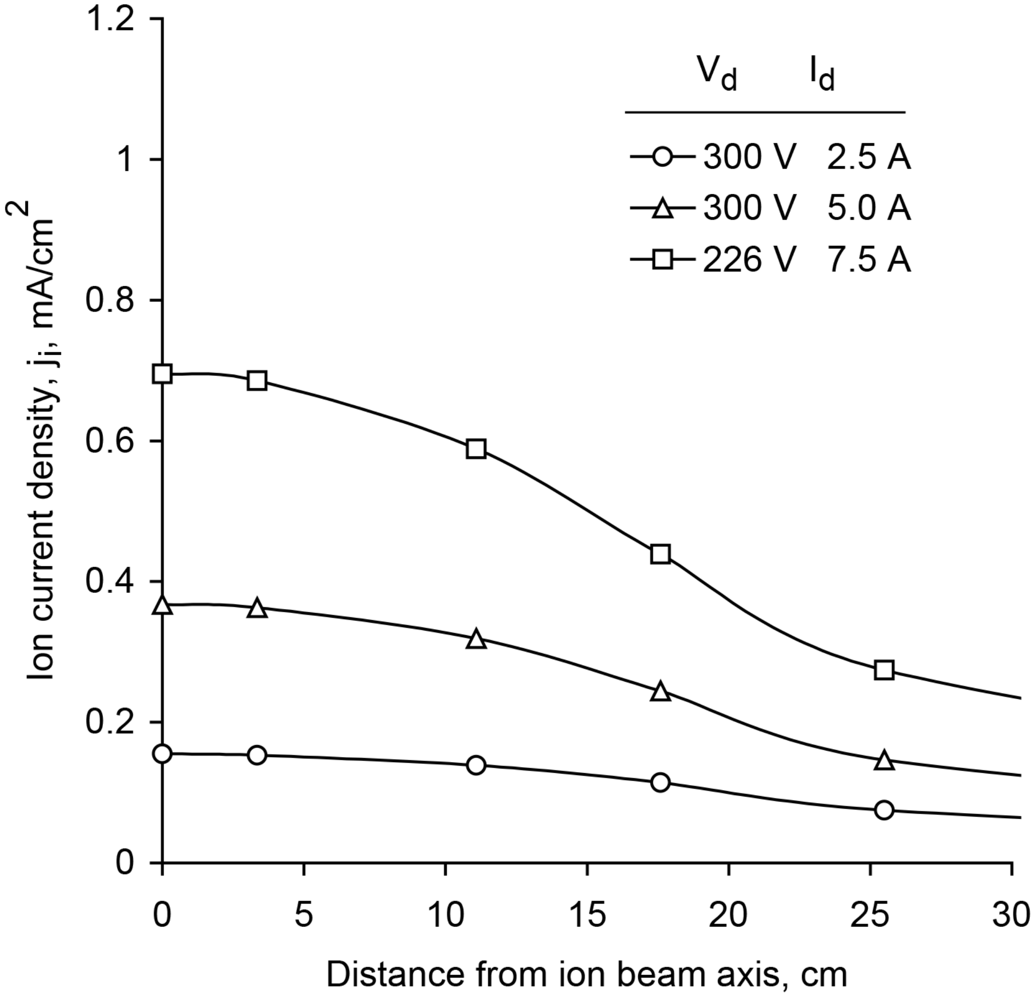

Figure 6-22. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

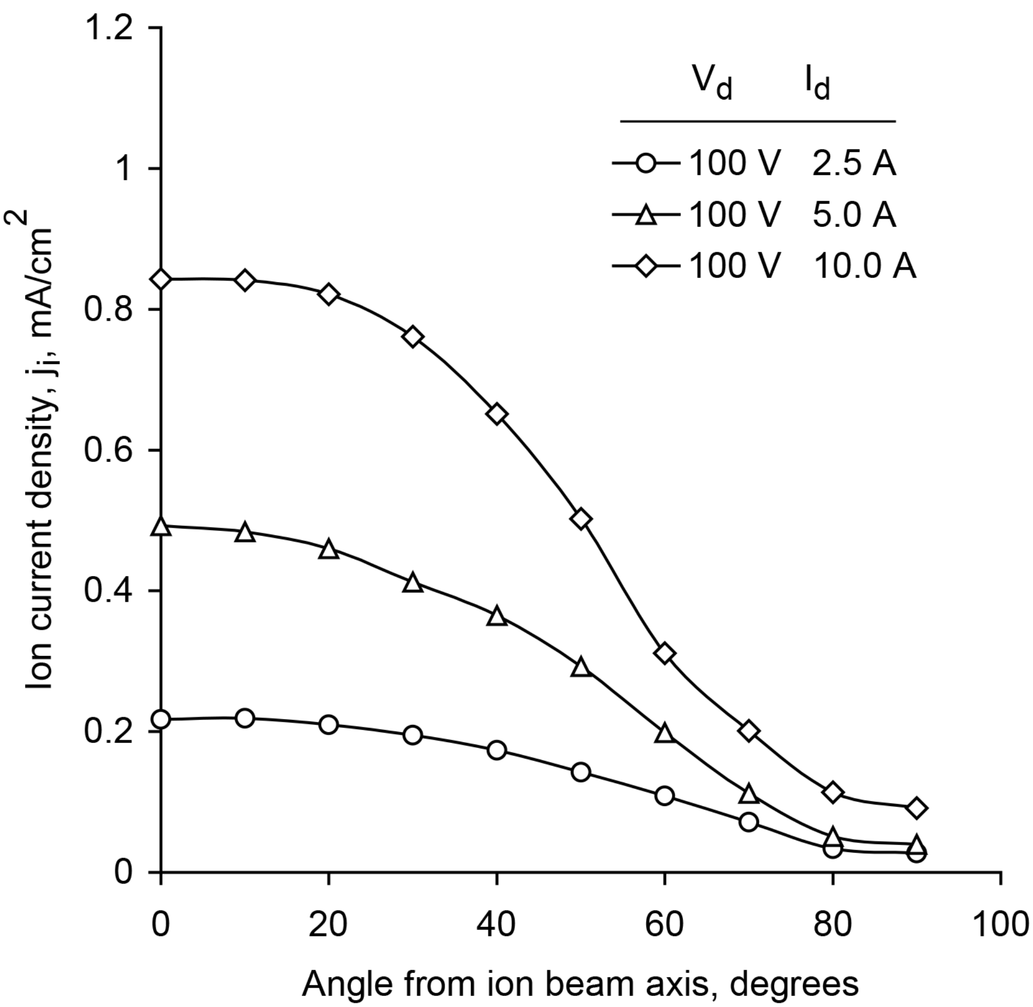

Figure 6-23. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

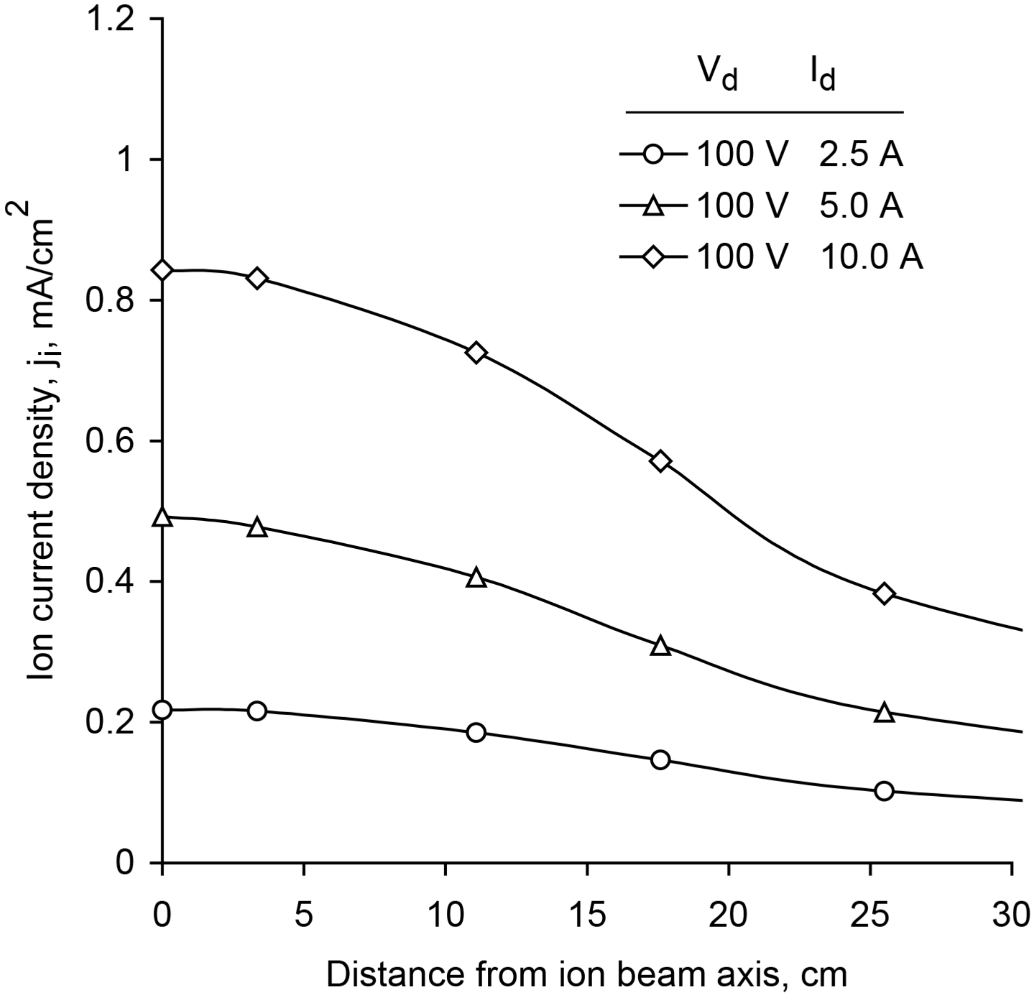

Figure 6-24. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

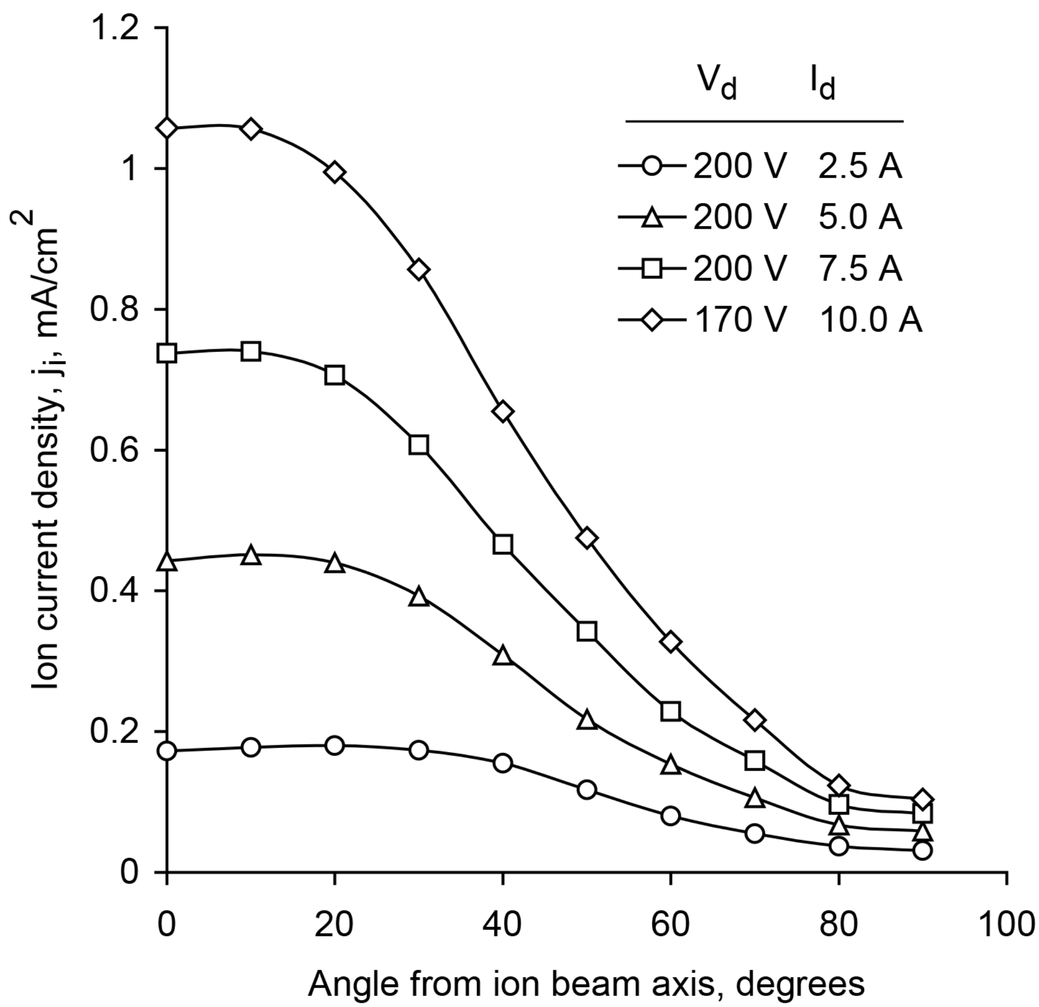

Figure 6-25. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

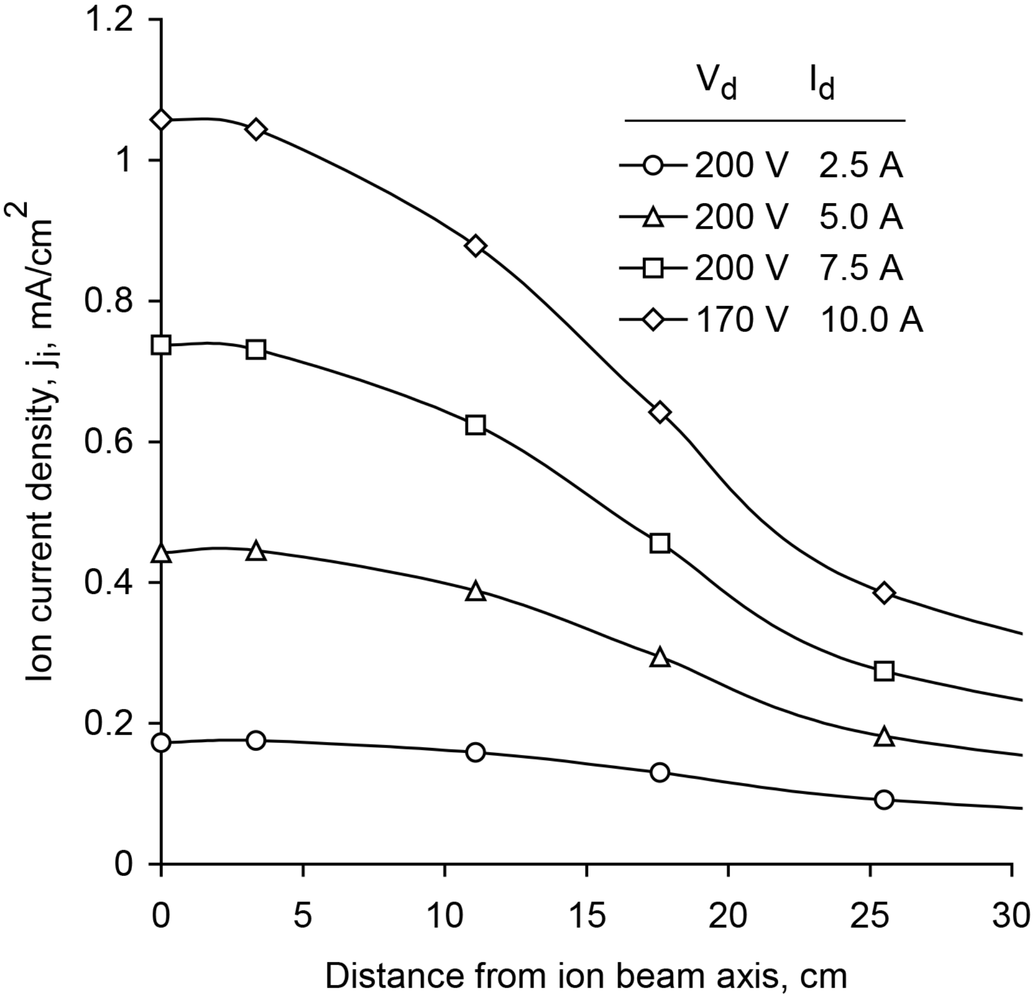

Figure 6-26. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

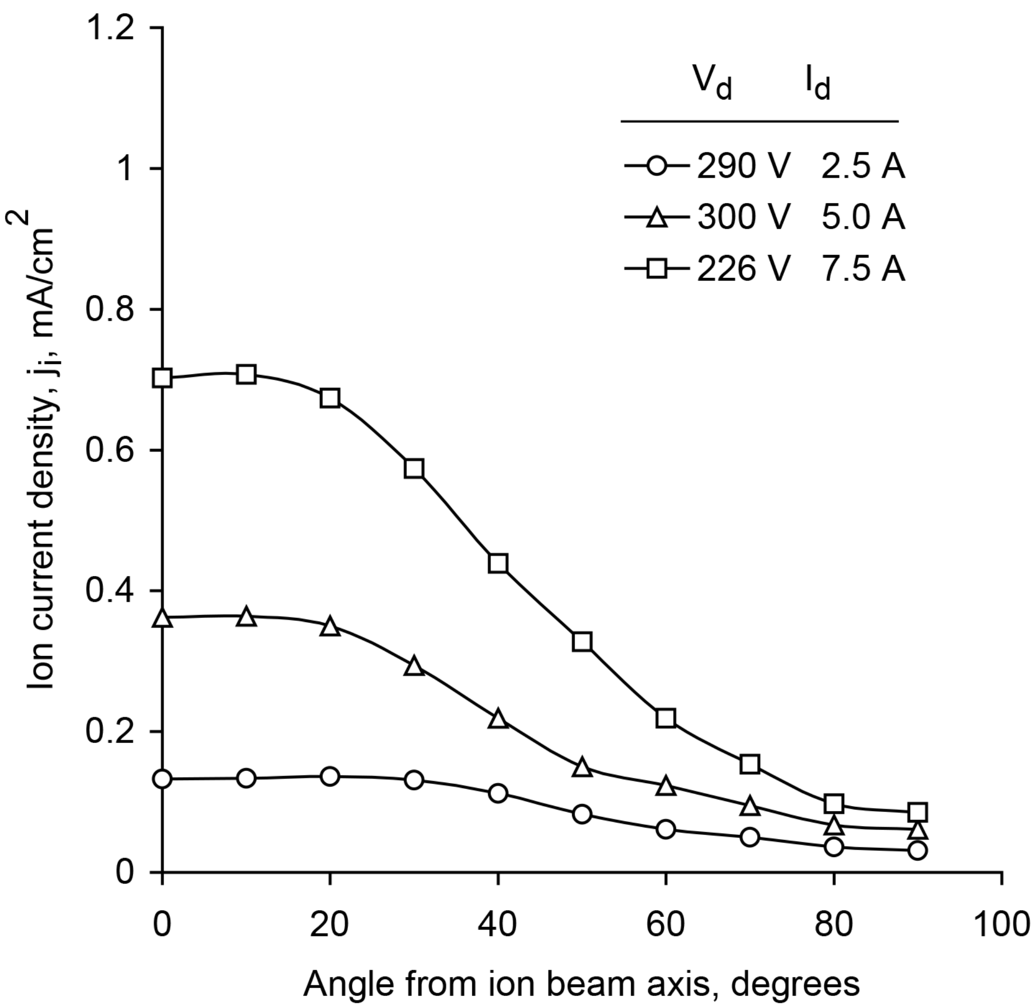

Figure 6-27. Spherical ion current density profiles for the KRI® eH2000HC ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

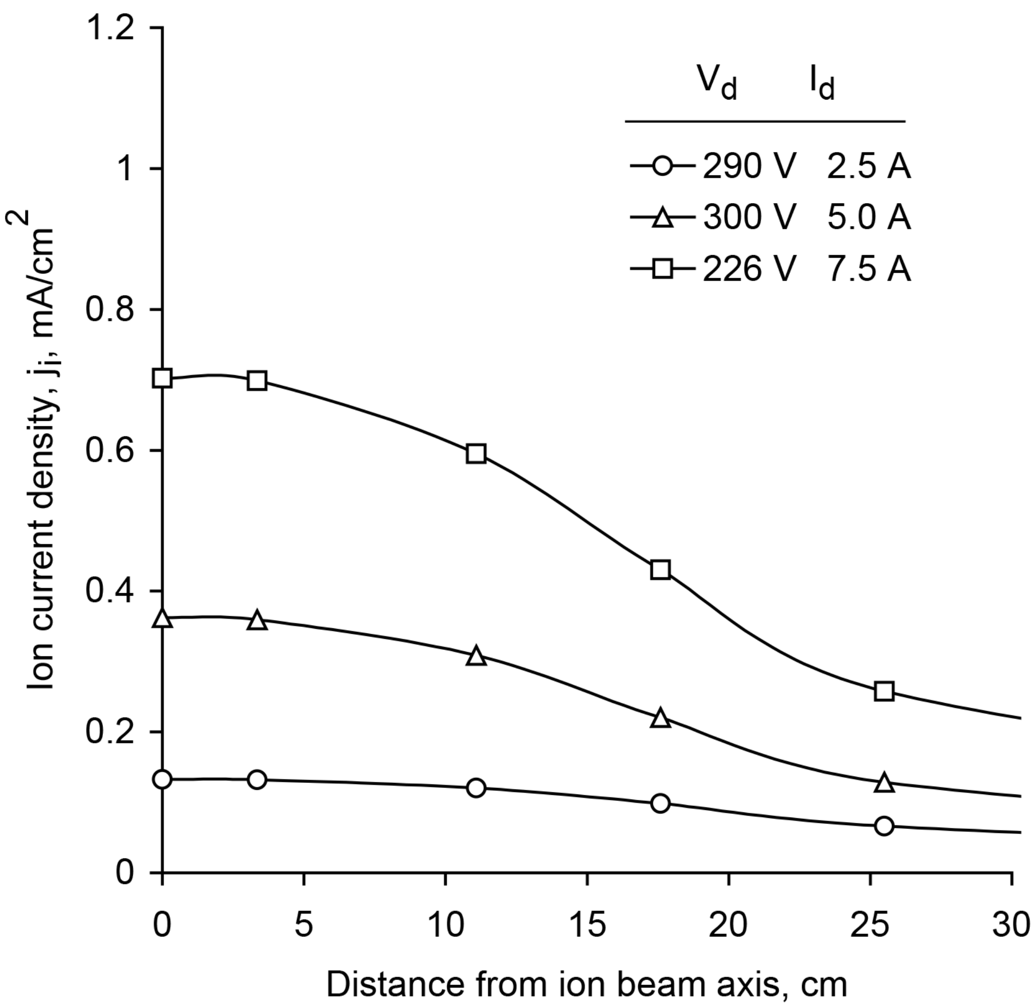

Figure 6-28. Flat target ion current density profiles for the KRI® eH2000HC ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

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7. MAINTENANCE

Before maintenance steps are carried out, make sure the power supplies are shut off and disconnect the electrical cables from the feedthroughs.

The source was designed for ease of maintenance. In addition to the modular construction, threaded parts are mostly oversized and in some cases gold plated to prevent galling. Do not over-tighten threaded parts. Finger-tightening should be adequate for most threaded parts. Wrenches should be used only when there is unusual resistance. The threaded parts most likely to gall and seize were also made small enough that they can be broken off and replaced with new nuts and screws.

7.1 Gas Line or Gas Bottle Replacement

CAUTION:
All maintenance should be carried out while wearing clean lint free gloves.

If a gas bottle is replaced or gas lines have been disconnected, proper procedure should be performed to avoid contamination. Refer to Inspection and Installation Section 2 for the proper procedure.

7.2 Hollow Cathode Electron Source

Assuming proper installation and power to the electron source, maintenance is required when it will not start or when the emission is inadequate. If the hollow cathode will not start, review the hollow cathode electron source manual for instructions on maintanance for assistance.

7.3 Ion Source

Occasionally the insulators that electrically isolate the anode and reflector from the rest of the ion source may need to be replaced, or flakes of material may need to be removed. Before maintenance of the ion source can begin, disconnect the electrical cable from the feedthrough and allow the source to cool for a minimum of 5 minutes at vacuum followed by 30 minutes at atmosphere.

7.3.1 Modular Anode Assembly

WARNING:
Source may still remain too hot to touch.

Remove the anode module from the main module by removing the two acorn nuts from the ion source front plate and place the anode module on a safe work surface with the front plate facing down (Figure 7-2 and Figure 7-3). Remove the three ¼-20 gold plated socket head cap screws from the gas distributor assembly and place the gas distributor assembly with the anode facing down on the work surface (Figure 7-4). Next remove the three 10-32 nuts, washers, and 10-32M insulators illustrated in Figure 7-4. The gas distributor assembly may now be removed exposing four10-32M insulators and the gas reflector that need to be removed (Figure 7-5). After removing the insulators and gas reflector, the remaining four 10-32M insulators and sputter covers may now be removed (Figure 7-6). This completes the disassembly of the modular anode assembly. Replace any of the 10-32M insulators if they appear to be damaged or coated. Contact KRI® for any replacement parts.

7.3.1.1 Anode

The anode may require cleaning after considerable use. Use silicon carbide abrasive paper in increasingly fine grades to clean the anode. Another common technique for cleaning is to use abrasive particles blown by gas jet (often called bead blasting). Clean aluminum oxide particles must be used to avoid the introduction of additional impurities during this cleaning process.

7.3.1.2 Water Break Replacement

To replace the water breaks for the eH2000 follow the steps outlined in Figures 7-2 through 7-7, and loosen the ¼ inch Swaglok™ nuts and remove the water break from the anode (Figure 7-7).

Note: The water break must be put back on in the same orientation as it was taken off. This will ensure there is no water leakage inside the ions source. The disassembly of the modular anode is now complete.

7.3.1.3 Anode Connector

The anode connector is shown in Figure 7-9. It is mounted to the inner ring, which can be found inside the main module. It connects to the anode contact rod located in the modular anode assembly. The anode connector has two 10-32M insulators on each side of the inner ring that may need to be replaced if coated or damaged. Through extended use, the anode connector may expand outward causing a poor electrical connection if this occurs it may be necessary to lightly bend the outer walls of the anode connector inward to insure a tight connection to the anode contact rod.

7.3.2 Reflector

The material used for the reflector will vary according to the working gas used. High density graphite should be used for inert gases, and stainless steel should be used for oxygen and other reactive gases, or if a mixture of oxygen and argon is beign used. Other reflectors such as titanium and tantalum are available for special applications. Reflector wear should be checked frequently until a wear rate and replacement schedule can be established for the particular operating conditions. Other parts of the ion source can be damaged if the reflector is permitted to wear through. Disassembly should be required only for replacement of the reflector, insulators or for cleaning after considerable use. Removal of the reflector is outlined in Section 7.3.1., during the disassembly of the anode module assembly.

7.3.3 Reassembly

Reassemble the ion source in the reverse order that it was disassembled. An alignment notch is located on each part. As each part is installed, position this alignment notch in the same circumferential location as the alignment notch on the previous part. The anode module alignment notch can be lined up with the location of the discharge connection on the outer shell.

7.3.4 Relevant Parts List

Table 7-1 is a list of relevant parts and the corresponding part number that can be purchased from KRI®. These parts are typically changed if the ion source will be used with a gas other than what if was originally specified for, or if contamination is a concern. Contact KRI® or refer to Section 2 for more information.

Table 7-1. Relevant parts list.

Description	Part Number
Reflector, high density graphite	EH10-12-CG
Reflector, pyrolytic graphite	EH10-12-C
Reflector, stainless steel	EH10-12-S
Reflector, tantalum	EH10-12-TA
Reflector, titanium	EH10-12-TI

Figure 7-1. Assembled ion source.

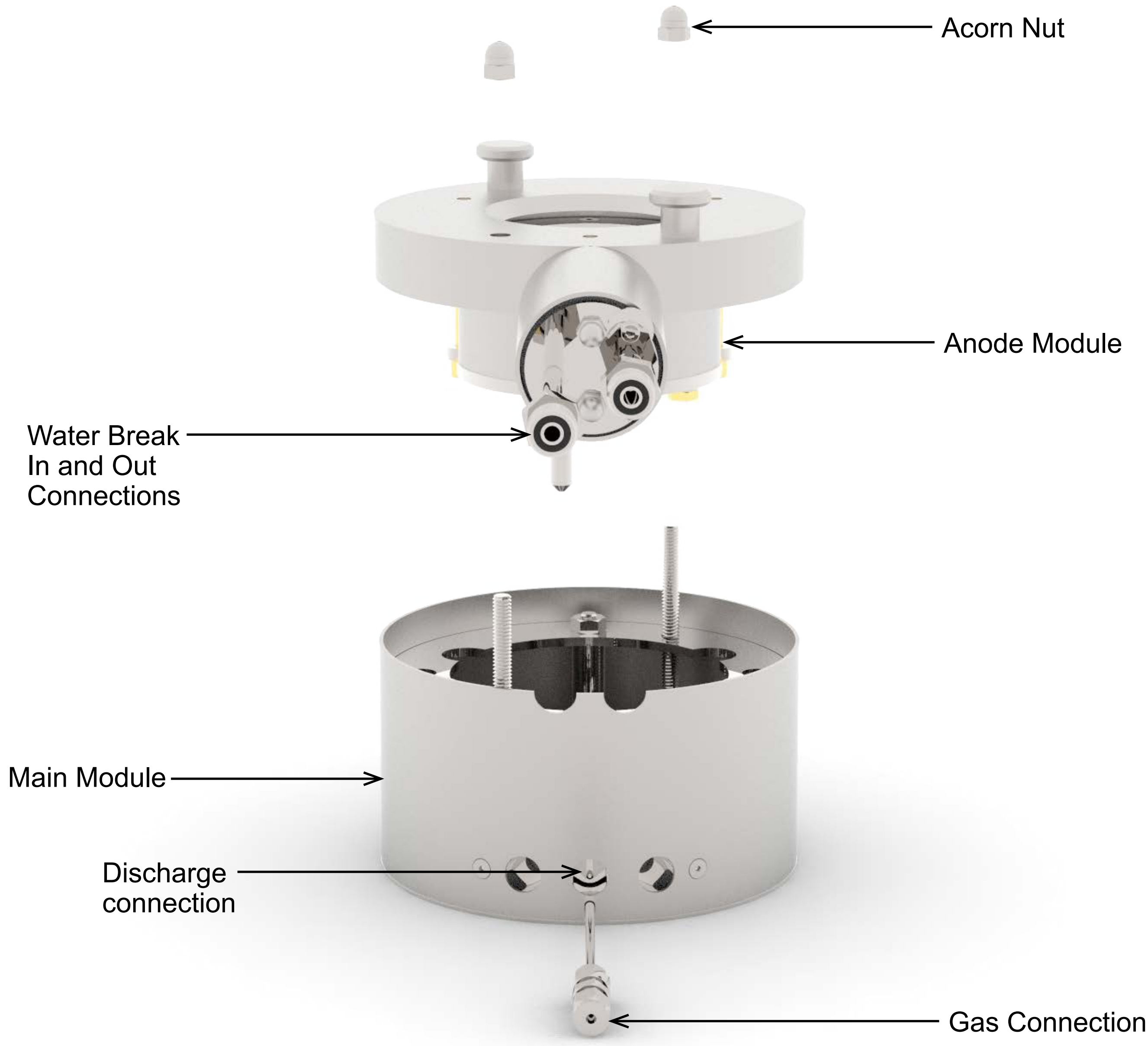

Figure 7-2. Cathode, cathode supports, and anode module removed from the main module.

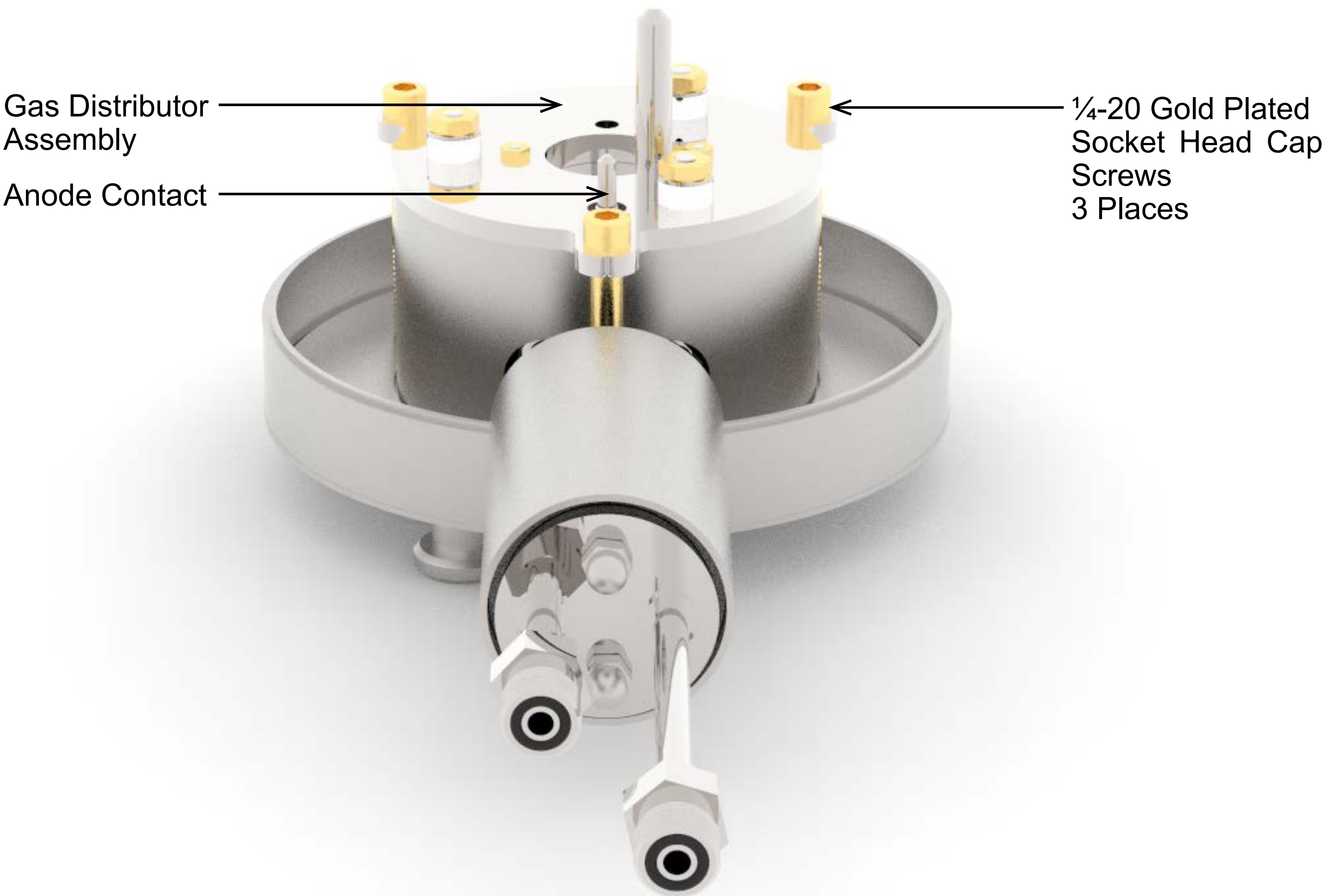

Figure 7-3. Modular anode assembly.

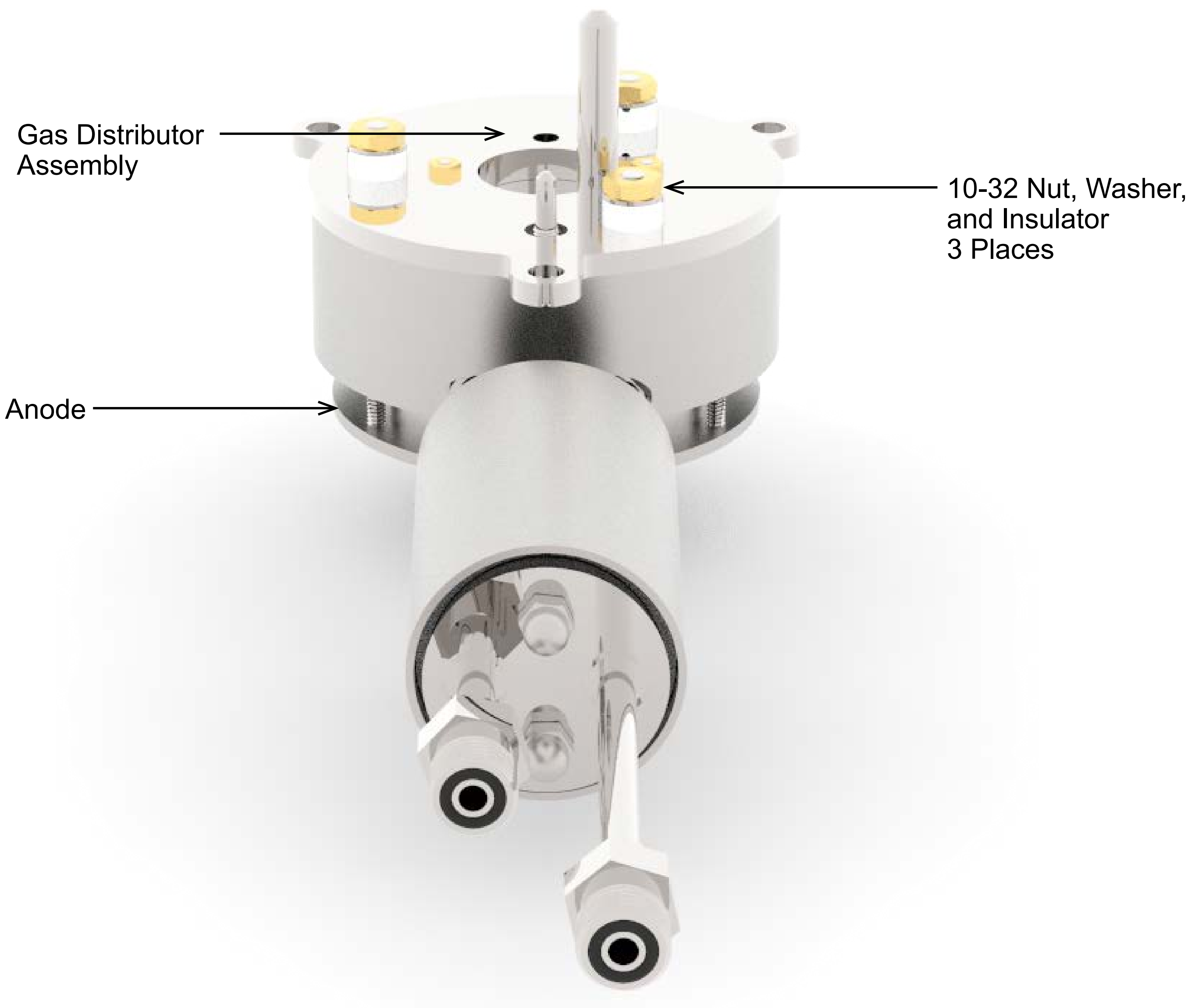

Figure 7-4. Gas distributor assembly.

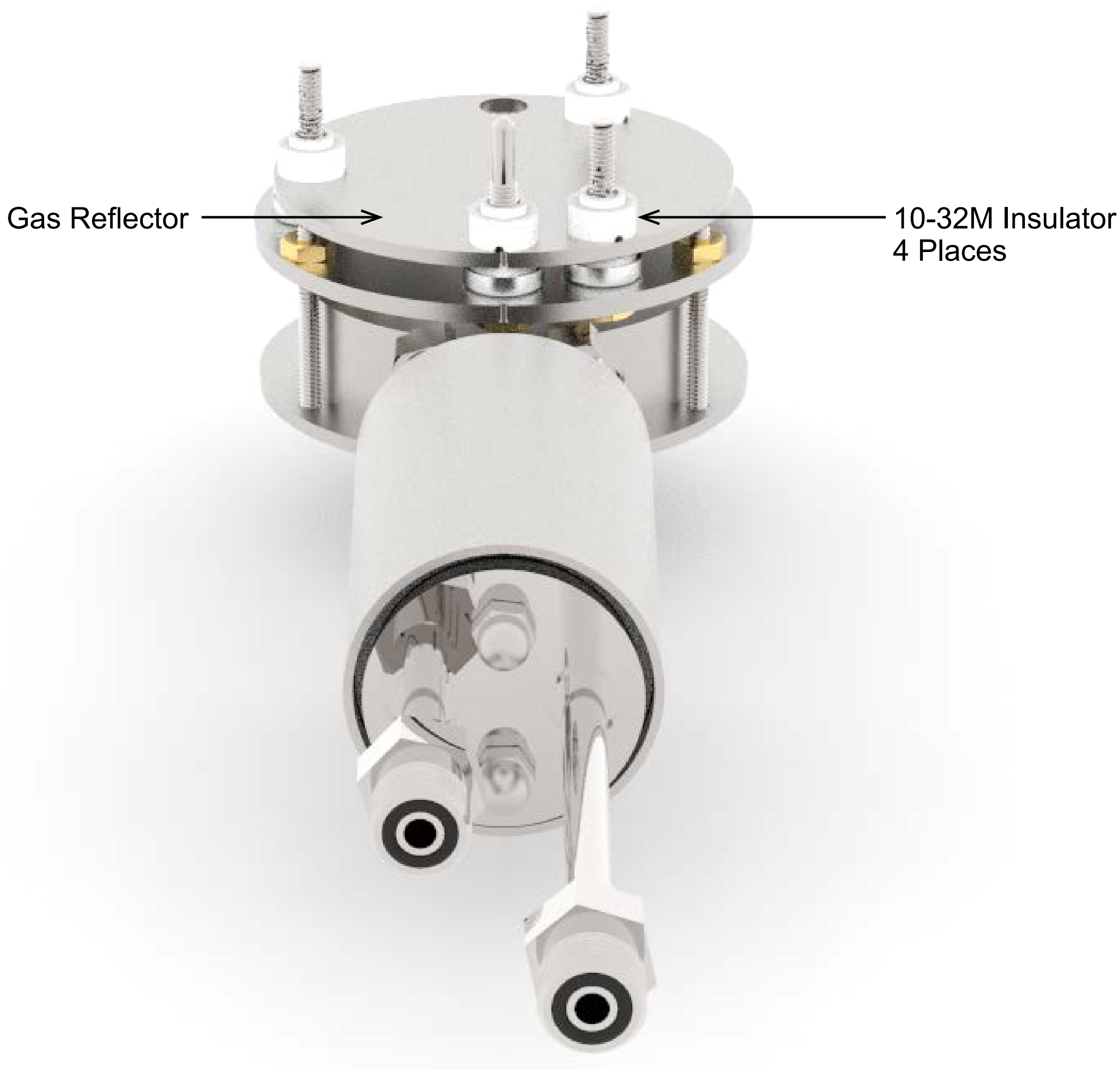

Figure 7-5. Gas reflector and 10-32M insulators.

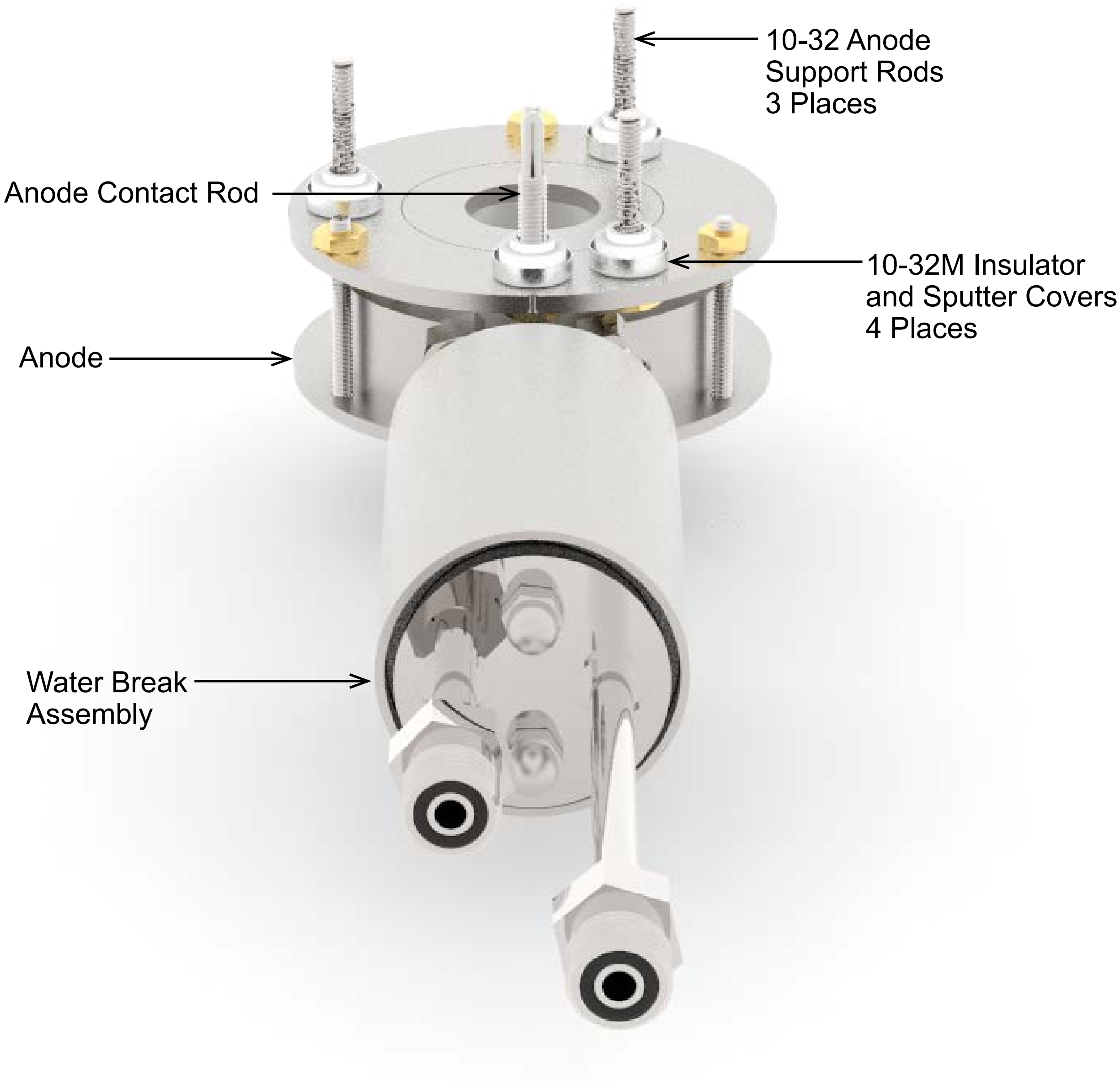

Figure 7-6. Anode support, 10-32M insulators and 10-32 sputter cups.

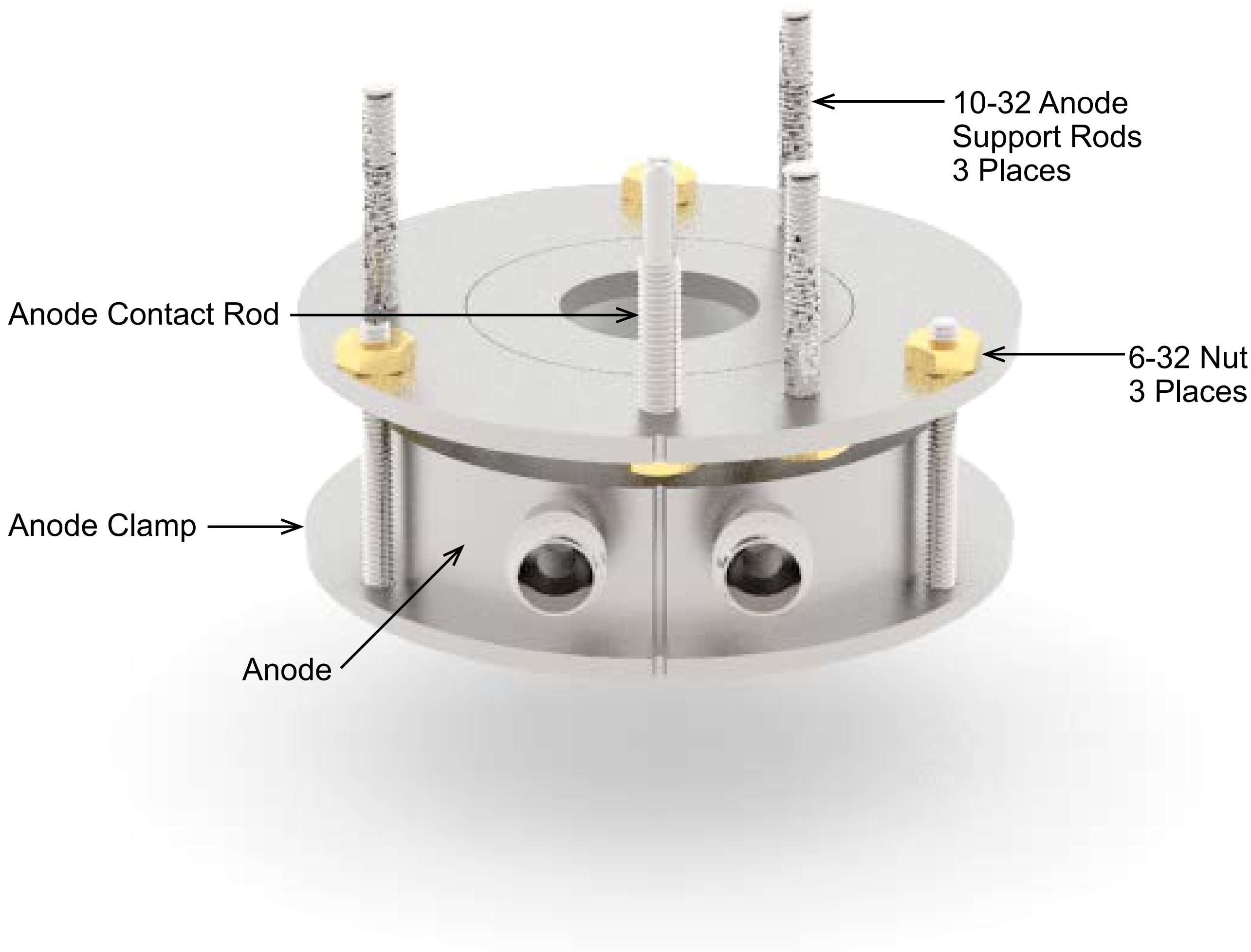

Figure 7-7. Anode and support with water break removed.

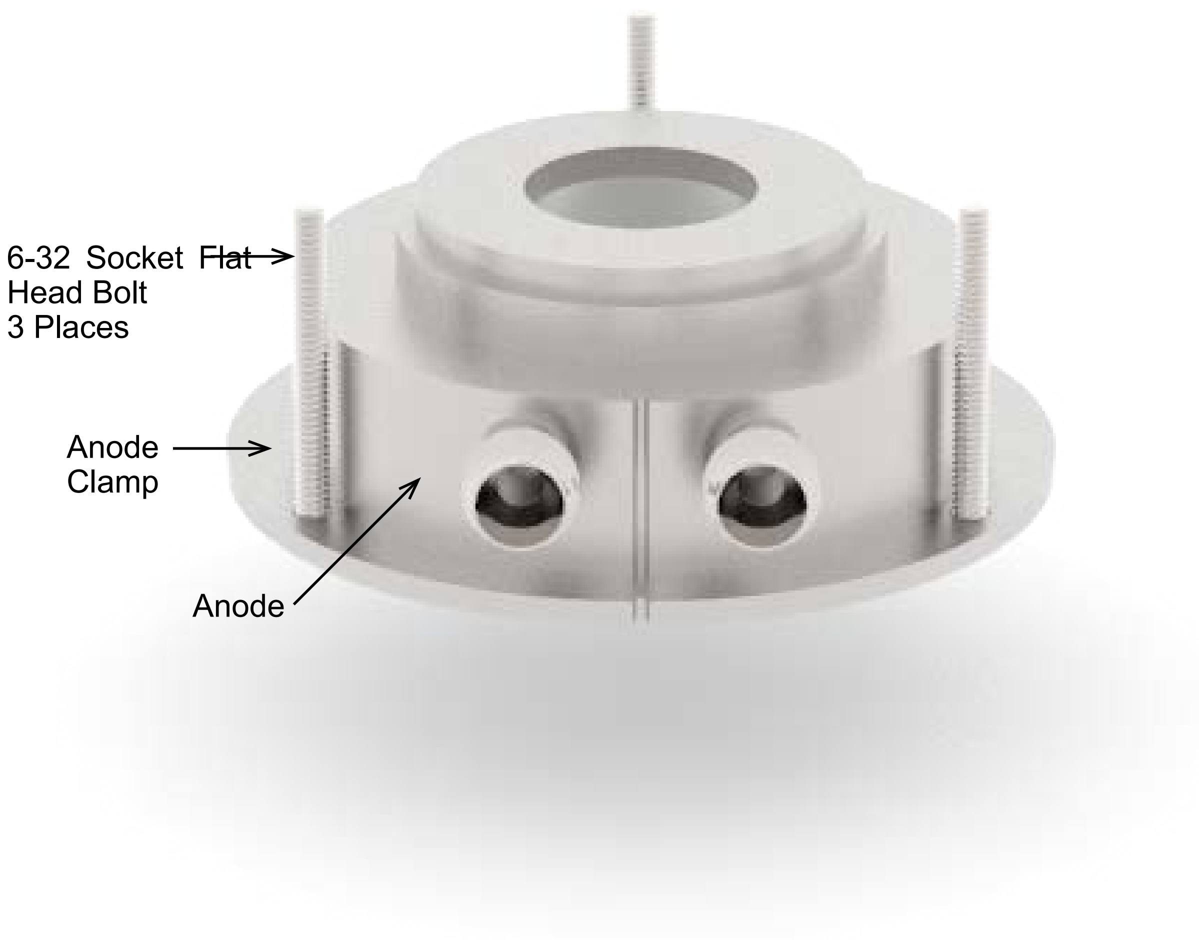

Figure 7-8. Anode and 6-32 machined screws.

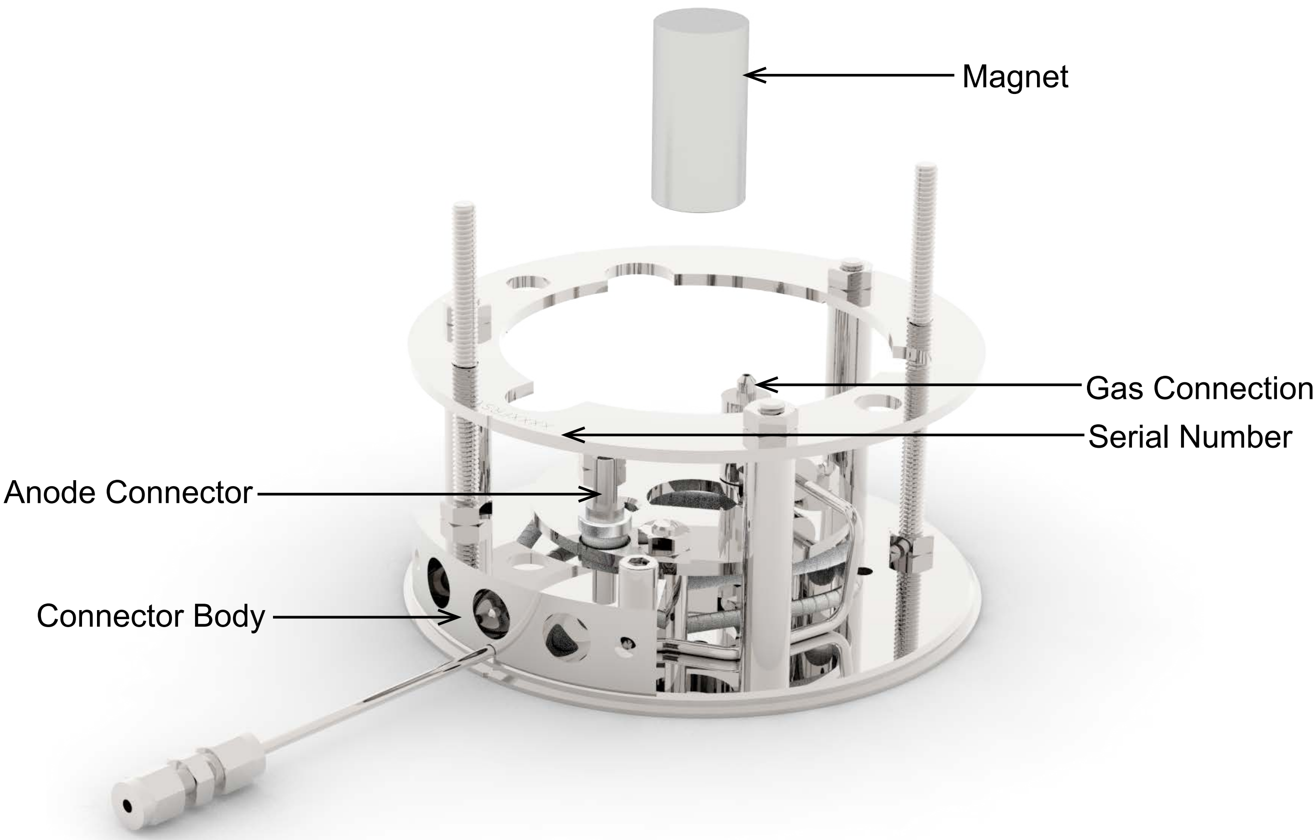

Figure 7-9. View of the main module with the outer cylinder removed.

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8. DIAGNOSTICS

8.1 General

The following information is intended to facilitate troubleshooting and repair of the eH2000HC water cooled anode ion source. This information assumes that all power supplies are connected to power and that all interconnects between the power supplies and the ion source cable are made correctly. It is also assumed that all gas and water connections are in good condition and that the gas circuit is complete from the gas bottle to the ion source.

CAUTION:
Only technically qualified personnel should install, maintain, and troubleshoot the equipment described herin.

WARNING:
Power must be removed from the controllers prior to performing maintenance on the eH2000HC ion source.

8.2 eH2000HC

In the event that abnormalities occur in the starting or operation of the eH-2000HC ion source, an ohmmeter check of the source can be done at the electrical feedthrough to assist in determining a fault. An ohmmeter check can be made prior to venting the vacuum system to atmosphere. An ohmmeter check from the discharge (anode) can be made from the electrical feedthrough to ground. A resistance less than maximum will indicate the necessity of maintenance on the eH2000HC ion source, electrical feedthrough or the vacuum cable. If the ohmmeter reads maximum when the ohmmeter is connected from the electrical feedthrough to ground, then the failure is not likely due to an anode-to-ground short at the ion source. Further testing with an ohmmeter would then be required to determine if a short is occurring between the controller and the ion source cable.

Another possible failure could be an open circuit condition. Testing the anode circuit for an open can be done in part by testing the power supply output, through the ion source cable to insure continuity. If there is good continuity between the power supply and the ion source cable the vacuum system will need to be vented to check the continuity between the electrical feedthrough and the ion source anode.

Oxide layers can accumulate on ion source hardware, which can inhibit starting of the ion source but may not be evident visually or with an ohmmeter check. Testing the anode for non-conductive coatings can be done using an ohmmeter while applying the rounded sides of the probe tips to various locations on the anode. Some oxide layers can be thin or delicate but are enough to cause starting problems. Testing for a non-conductive coating using the pointed probe tips can break through this coating giving a false indication of the cleanliness of the anode.

8.3 Diagnostic Table

The following table may be used to assist in determining faults and corrective action for the eH2000HC ion source.

Table 8-1. Diagnostic table.

Symptom	Possible Cause	Correction
Inability to start hollow cathode electron source	• Gas flow too low or leakage in gas line • Failure of the hollow cathode tip • Insulating coating on the cathode body and/or keeper • Keeper hole enlarged • Contaminated gas supply	• Increase gas flow or tighten fittings • Replace hollow cathode tip and associated hardware • Perform maintenance on cathode, cleaning the keeper and body • Replace keeper • Refer to Inspection and Installation Section 2.4.3
Inability to start a discharge (Ion source), discharge voltage normal, no discharge current, cathode normal	• Low gas flow • Poor, incorrect, or loose electrical connections • Insulating layer on anode	• Increase gas flow, and/or calibrate flow controller • Check all electrical connections to insure electrical circuit is complete and the electrical connections are reliable • Clean the ion source anode

Symptom	Possible Cause	Correction
Discharge current high, discharge voltage very low	• Discharge (anode) short to ground	• Inspect electrical cables and feedthrough for damage, repair or replace if necessary • Insulators that isolate the anode and anode contact within the ion source need replacement
Excessive reflector erosion	• Reflector short • Incorrect reflector installed for the gas in use	• Replace coated insulators or remove any debris • Install the correct reflector

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9. WARRANTY

Seller warrants to the Buyer that new Products will be free of defects in material and workmanship and shall conform to applicable specifications for a period of one(1) years from date of shipment. Seller does not warrant uninterrupted or error-free operation of the firmware. Seller's obligation under these warranties is limited to repairing or replacing, at Seller's option, defective Products. These services will be performed, at Seller's option, at either Seller's facility or Buyer's business location. For repairs performed at Seller's facility, Buyer must contact Seller in advance for authorization to return Products and must follow Seller's shipping instructions. Freight charges and shipments to Seller are Buyer's responsibility. Seller will return the Products to Buyer at Seller's expense. All parts used in making warranty repairs will be new or of equal functional quality. Seller assumes no liability under the above warranties and the following are specifically excluded from all warranties including Product defects resulting from (1) abuse, misuse, or mishandling; (2) damage due to forces external to the Product including, but not limited to, Force Majeure, power surges, power failures, defective electrical work, foreign equipment/attachments, or utilities, gas or services; (3) the use of parts not supplied by the Seller; (4) replacement and repaired parts, and consumable items (including, but not limited to, filaments, insulators, isolators, vacuum cables, connectors, and gas reflectors); (5) improper operation or maintenance, servicing, installation or (6) failure to perform preventive maintenance in accordance with Seller's recommendations (including keeping an accurate log of preventive maintenance). In addition, this warranty does not apply if any Products have been modified without the written permission of Seller or if any Seller serial number has been removed or defaced. THIS WARRANTY IS GIVEN IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY, TITLE, NON-INFRINGEMENT, FITNESS FOR A PARTICULAR PURPOSE OR USE, OR OTHERWISE. IN NO EVENT SHALL SELLER'S TOTAL LIABILITY TO BUYER EXCEED THE PURCHASE PRICE OF THE PRODUCTS.

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