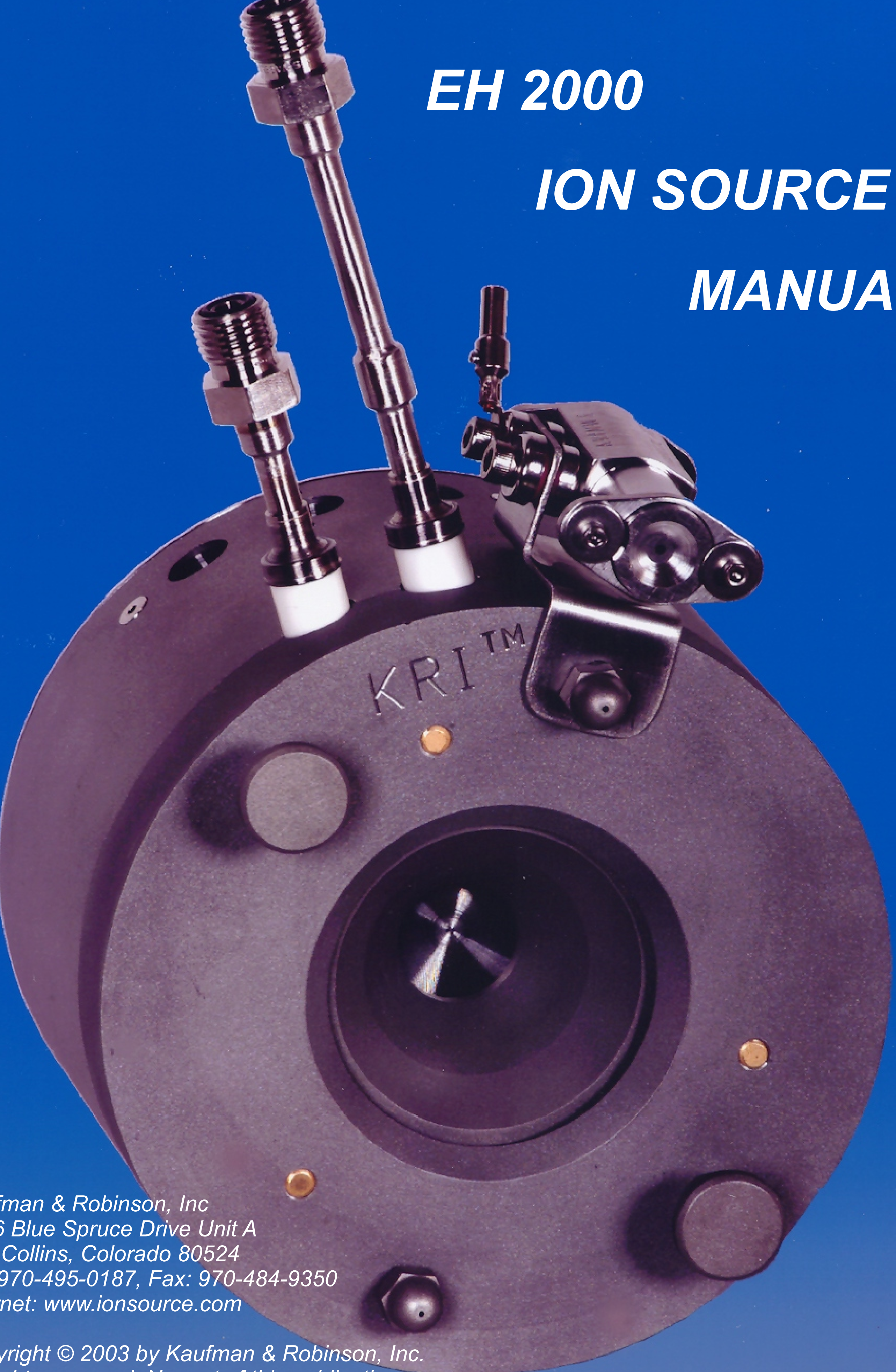
EH 2000

ION SOURCE

MANUAL



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VERSION 1.0

EH2000 ION SOURCE MANUAL
HCES VERSION

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SERIAL # ______________________________

CONTENTS

FIGURES

TABLES

1 SAFETY

Only technically qualified personnel should install, maintain, and troubleshoot the equipment described herein.

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 section describes how to install the Kaufman & Robinson, Inc., KRI ™ EH2000 Ion Source and hollow cathode assembly. 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 and the hollow cathode were inspected and tested and were shipped free of physical defects. As soon as the ion source and hollow cathode have been completely removed from all packing materials a visual inspection should be made to determine if there has been any damage to the products during shipment. If any damage has occurred contact Kaufman & Robinson, Inc., in addition to the shipping company to report any damage, see Warranty section 9. Retain packaging materials for storage or returning the ion source and hollow cathode for maintenance or upgrades.

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

2.2.1 EH2000 Ion Source The EH2000 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 hardware and alumina. Depending on the intended use of the ion source titanium, tantalum 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 oversize and in some cases gold plated to prevent galling. Do not overtighten 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, Fig. 2-1. Alignment of the two modules is facilitated using an alignment pin attached to the anode module that slides into a clearance hole in the main module. Gas and electrical connections to the anode module are made when the module is connected to the main module. Water connections are made using Swagelok™ VCO fittings for ease of use, Fig. 2-1.

2.2.1.2 Main Module The main module contains the magnetic circuit, electrical connections and associated support hardware for the anode module, Fig 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 back outer cylinder in this module. A gas connection is also made to the module. The main module has been designed so that minimal maintenance is required.

2.2.1.3 Vacuum Cables Vacuum cables have been supplied for the anode and cathode connections that are made from the electrical feedthrough to the ion source and the cathode. 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.

2.2.1.4 Hollow Cathode Electron Source The hollow cathode has been designed to be operated for long lifetime in addition to ease of maintenance. The hollow cathode assembly is fabricated primarily of stainless steel, alumina and tantalum and is shown in figure 2-1. Maintenance of the cathode has been made more efficient by utilizing small screws and nuts to attach most of the components to the cathode body, without the use of threaded holes in the components. In the event of seizing, they can be broken off and replaced with new screws. This approach prevents screws from seizing in the cathode body thus requiring less maintenance.

2.3 Inventory

Table 2-1 outlines the required hardware necessary for installation and operation of the ion source, which are shipped with each ion source.

Three components of the ion source are changed for inert and reactive gases; the reflector, anode and magnet. The material of the reflector can be either graphite for inert gases or stainless steel for reactive gases. 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. The magnet is changed to improve the performance of the ion source with inert or reactive gases.

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. It is possible to operate the ion source with the alternate anode and magnet for a particular gas, but doing so will limit the range of operation for the ion source. Refer to the alternate parts list in the Maintenance section 7 for part numbers and descriptions of the anode and magnet. Contact KRI to purchase an alternate anode and magnet.

Only one of the part numbers marked with an asterisk (*) is included.

Table 2-1. Inventory List.

Quantity	Description	Part Number
1	End-Hall 2000 ion source	EH2000-HC
1	Hollow cathode assembly	SHC1000
1	Vacuum discharge cable	CBL-A01A-VAC-DS-EH
1	Vacuum hollow cathode cable, cathode	CBL-A03A-VAC-HC-CA
1	Vacuum hollow cathode cable, keeper	CBL-A03A-VAC-HC-KP
1	Atmosphere cable hollow cathode	CBL-A06-ATM-HC-EH
1	Electrical feedthrough assembly	FDT-A100-ELE-EH
1	Feedthrough, water, hollow cathode	FDT-A102-WATER-HC-EH
1	Feedthrough, gas, hollow cathode	FDT-A102-GAS-HC-EH
1	Spare reflector, pyrolytic graphite	EH10-12-C *
1	Spare reflector, stainless steel	EH10-12-S *
1	Spare parts kit	EH10-SP

2.4 INSTALLATION

The EH2000 Ion source is typically installed at a source-substrate distance of 30-60 cm (12 - 24 in.) from the substrate.

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, for a hot filament version, the cathode. If necessary, a stainless steel 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 Section 5 for further considerations regarding placement of the ion source within the vacuum facility.

2.4.1 Ion Source Mounting Installation of the ion source, hollow cathode, and associated hardware can be facilitated with the use of figure 2-2 thru 2-5. 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. **Use clean lint free gloves to handle any of the components to prevent contamination.**

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, Fig. 2-2. 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 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 are shown in figure 2-2. Mounting holes are also provided in the transit support for installation in the vacuum facility. The locations of these mounting holes are shown in Fig. 2-3. 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 2-4 shows the location of these nuts. The acorn nuts prevent deposition on the threads, which would otherwise be exposed.

2.4.3 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 2-5 and 2-10.

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°Celcius, maximum.

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

2.4.4 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 can contaminate the ion source and hollow cathode electron source, resulting in premature failure of the electron source. Gas connections can be made with reference to figures 2-5 and 2-9.

The electron source requires high purity argon or xenon gas, at least 99.999% pure. The use of lower grade gases or leaks can reduce electron source lifetimes by signifficantly.

The EH2000 source can be operated on different gases. These gases must also be 99.999% pure.

Gas connections are made to the hollow cathode electron source and EH2000 source using Swagelok™ fittings. Mass flow controllers are used to regulate the gas flow to the ion source and electron source. Once the gas circuit has been completed from the ion source and electron source to the gas bottles, the gas lines should be evacuated to prevent contamination of the gases and the ion and electron source.

While installing the mass flow controllers, gas bottles, and gas lines 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 (not plastic tubing).
- 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.

2.4.5 Electrical Connections in the Vacuum System

2.4.5.1 Ion Source The electrical connection for the anode, or discharge connection is made from the electrical feedthrough, (figure2-8), 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. The anode connection is made in the center clearance hole as shown in figure 2-5. The cable end that mates with the ion source has a stainless steel 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. The holes on either side of the center plug are left open for venting. The gas is enclosed inside the ion source.

2.4.5.2 Hollow Cathode Electrical connection to the hollow cathode is made using two cables. 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.

2.4.5.2.1 Cathode Connection This cable connects from the hollow cathode at the gas line using a stainless steel female connector, as shown in figure 2-5. The other end of this cable connects to the electrical feedthrough assembly, see Electrical Feedthrough Connections, Vacuum Side. Section 2.4.6.1, below.

2.4.5.2.2 Keeper Connection This cable has a male connector on one end and an in-line connector on the other. The male connector will connect to a female connector located on the cathode body. The opposite end of this cable connects to the electrical feedthrough, see Electrical Feedthrough Connections, Vacuum side. Section 2.4.6.1, below.

2.4.6 Electrical Feedthrough Using standard vacuum practice, install the electrical feedthrough as shown in figure 2-5 through 2-8. To do so, loosen the four set screws on the safety enclosure, see figure 2-6a. The set screws near the connector end must be loose enough to allow the connector to rotate. Unscrew the safety enclosure from the electrical feedthrough. Remove the connector, anode wire and the two HCES wires from the feedthrough by loosening the screws on the inline connectors. Install the feedthrough in a 1 inch port of the vacuum chamber. Then reinstall the wires and connector to the feedthrough. Refer to Fig. 2-6b for proper locations, and then reinstall the safety enclosure.

2.4.6.1 Electrical Feedthrough Connections, Vacuum Side Connections from the ion source and hollow cathode are made to the electrical feedthrough as follows with the use of figure 2-5 and 2-6. When attaching the cables to the electrical feedthrough, first loosen the set screws on the feedthrough sputter cover and remove it from the feedthrough. Insert the cathode, keeper and discharge (anode) cables through the appropriate holes of the feedthrough sputter cover. Refer to figure 2-6b for orientation. Slide the feedthrough sputter cover and the loom of the cables back to expose the inline connectors. Attach the inline connectors to the feedthrough in the proper orientation. Stretch the fiberglass loom over the connectors and return the feedthrough sputter cover back in place on the feedthrough and tighten the set screws.

2.4.6.2 Electrical Connections at Atmosphere A cable has been provided for connection from the power supplies to the electrical connector attached to the safety enclosure. See fig. 2-6. The cable end uses a locking mechanism to secure the connectors. For electrical connections at the power supplies refer to the controller manual.

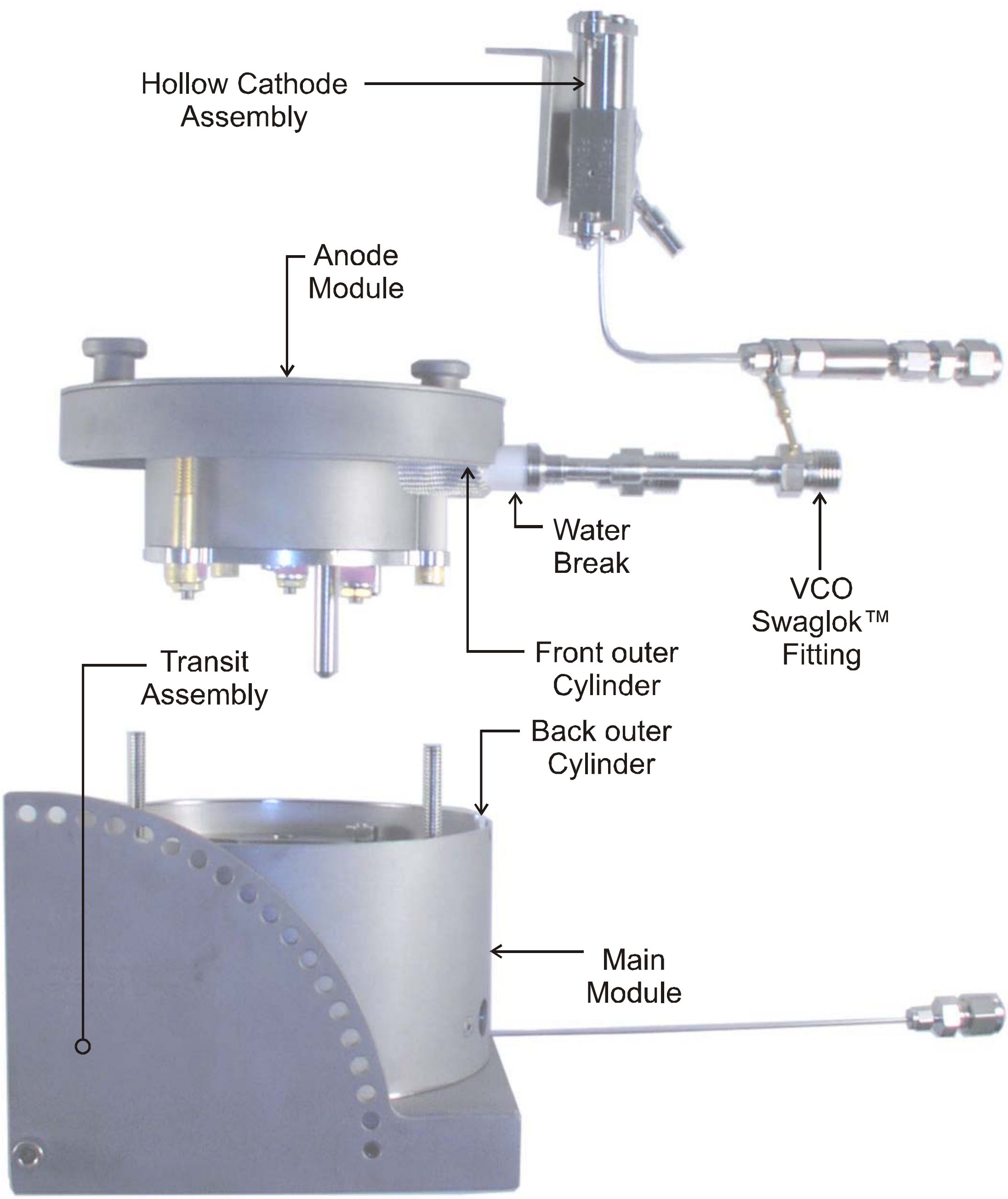


Fig. 2-1 The EH2000 Ion source with the hollow cathode and anode module removed.

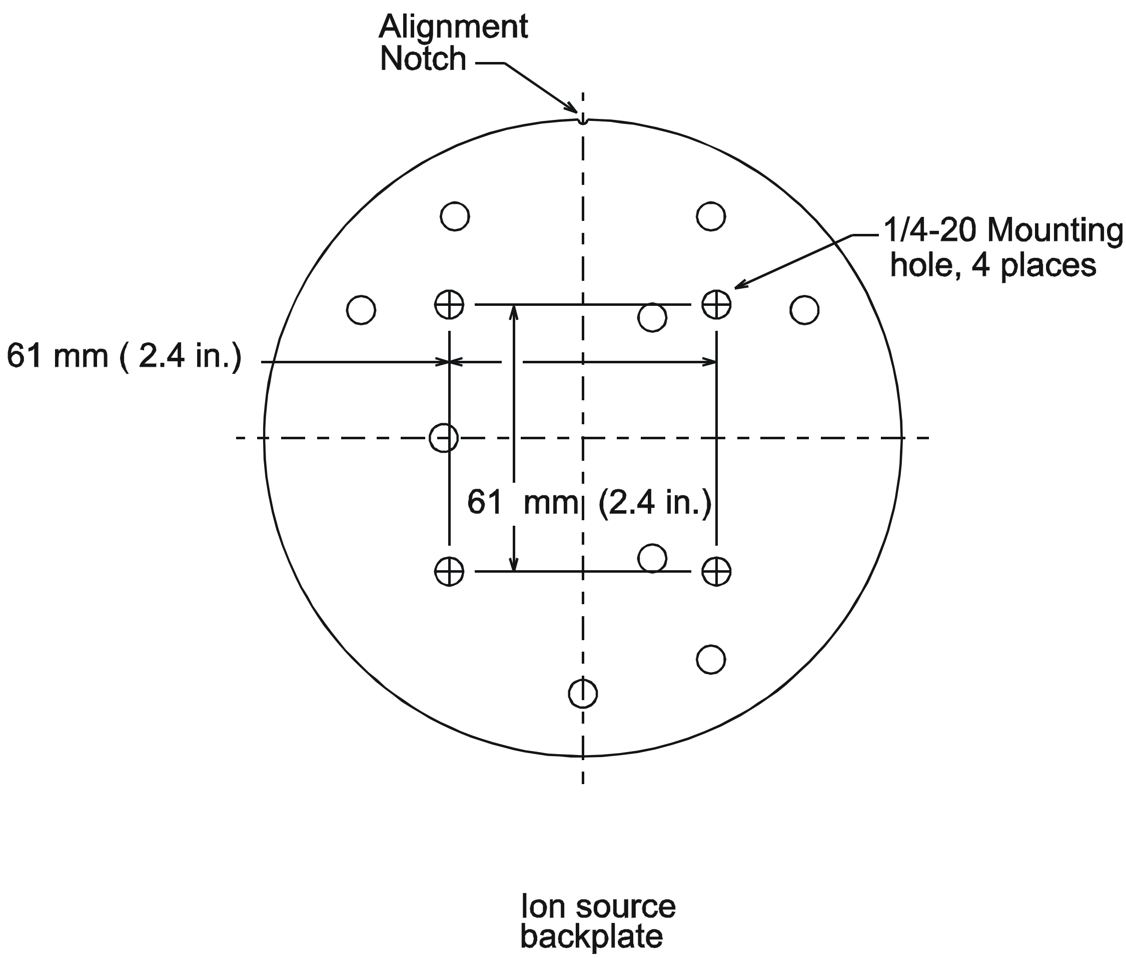


Fig. 2-2 Mounting hole locations for the EH2000 ion source.

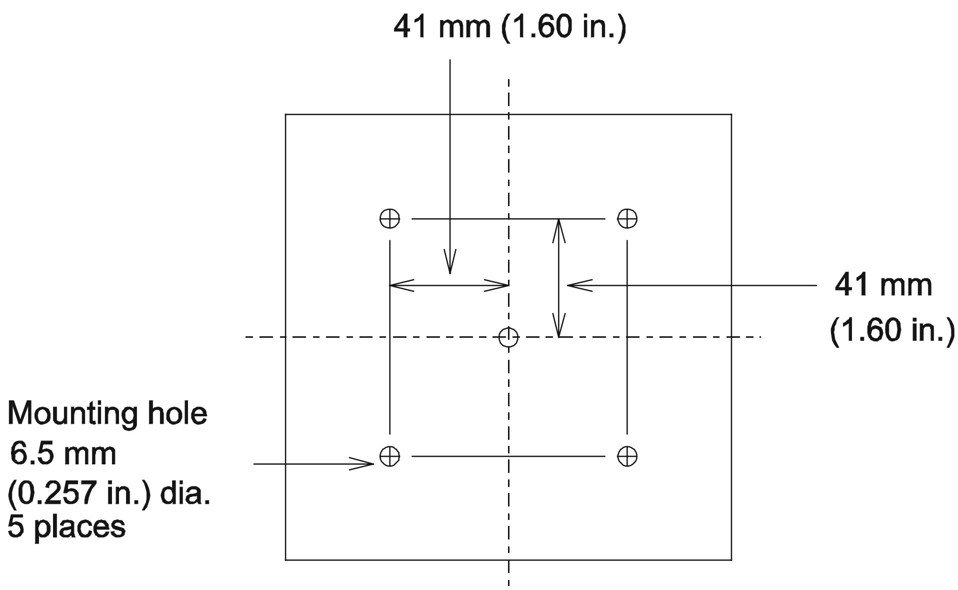


Fig. 2-3 Mounting hole locations for the transit support.

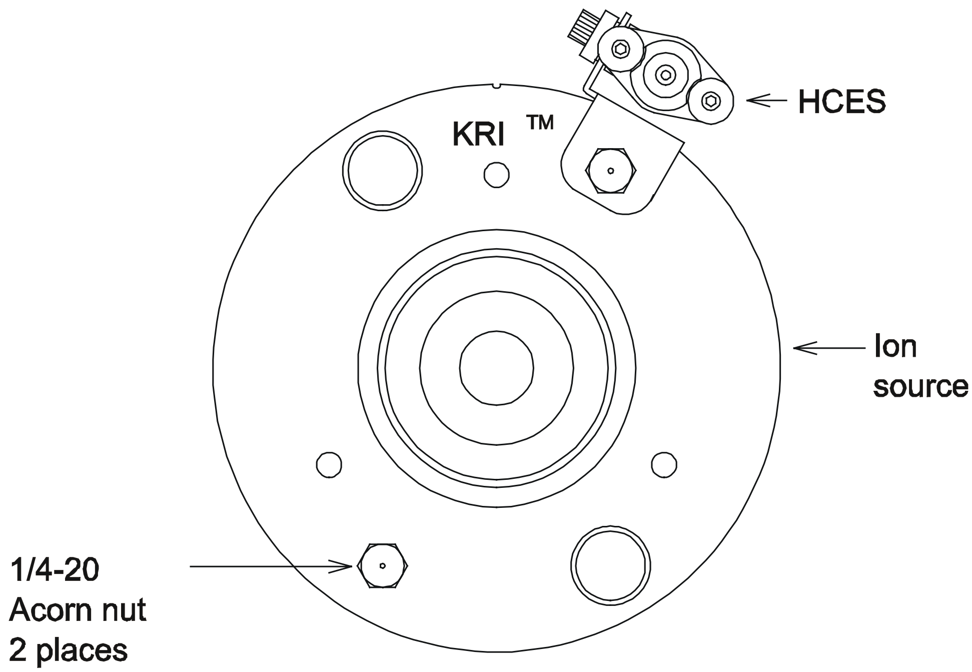


Fig. 2-4 Hollow cathode mounting.

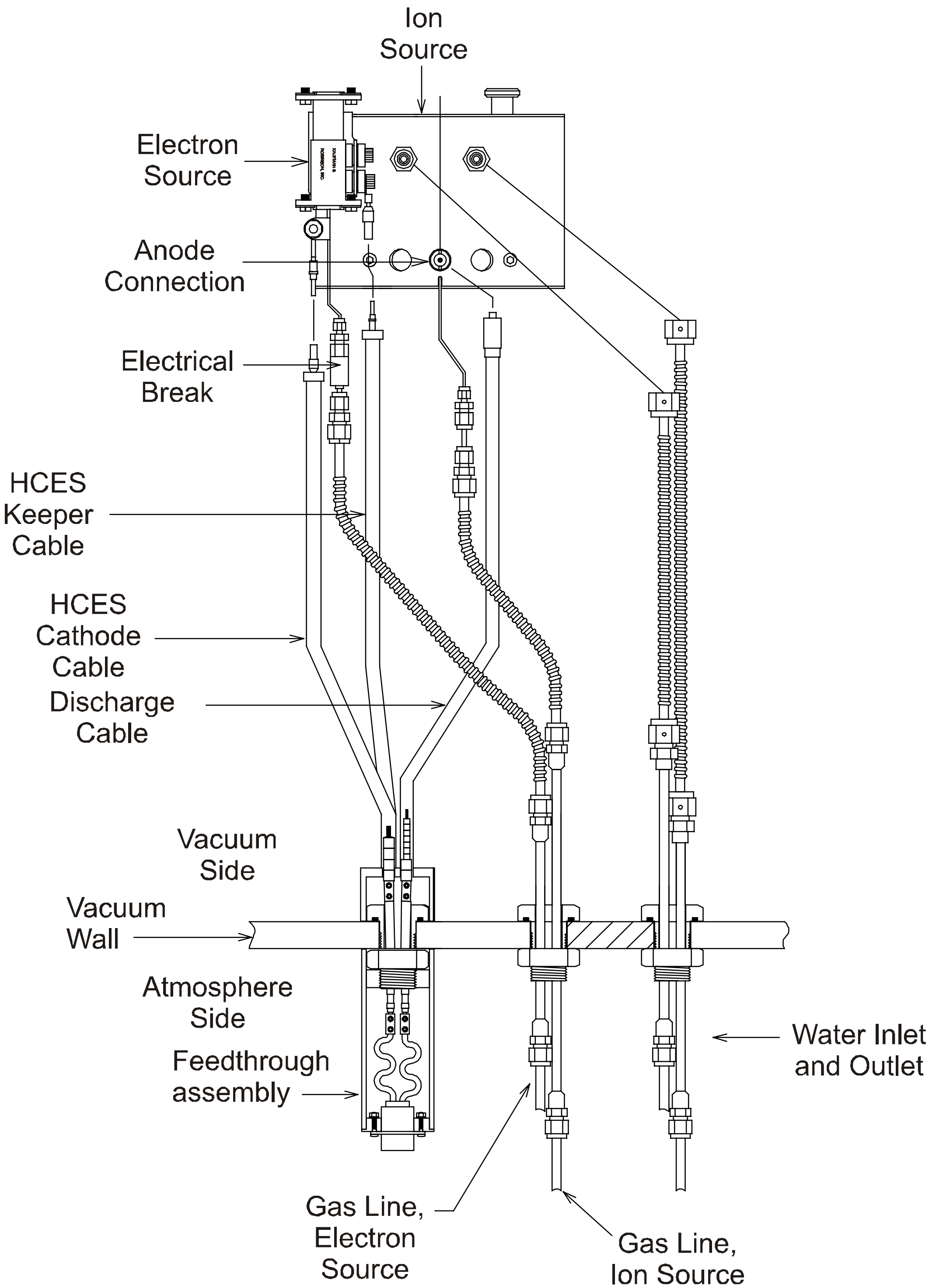
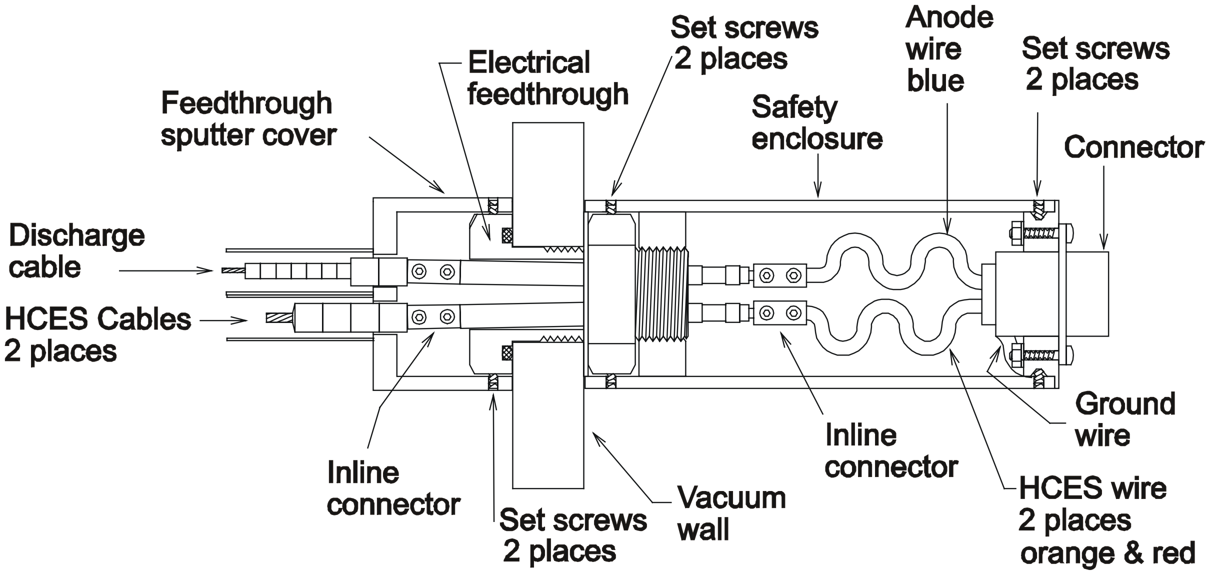
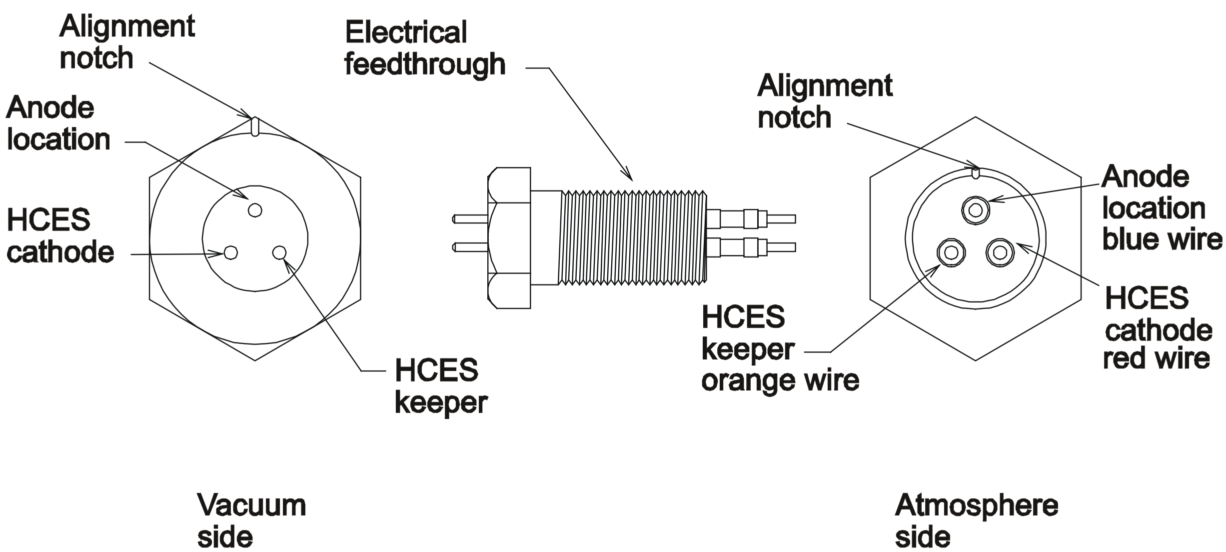


Fig. 2-5 Installation drawing for the EH2000.



a) Cutaway view of the electrical feedthrough assembly.



b) Electrical feedthrough.

Fig. 2-6 Detailed view of electrical feedthrough assembly.

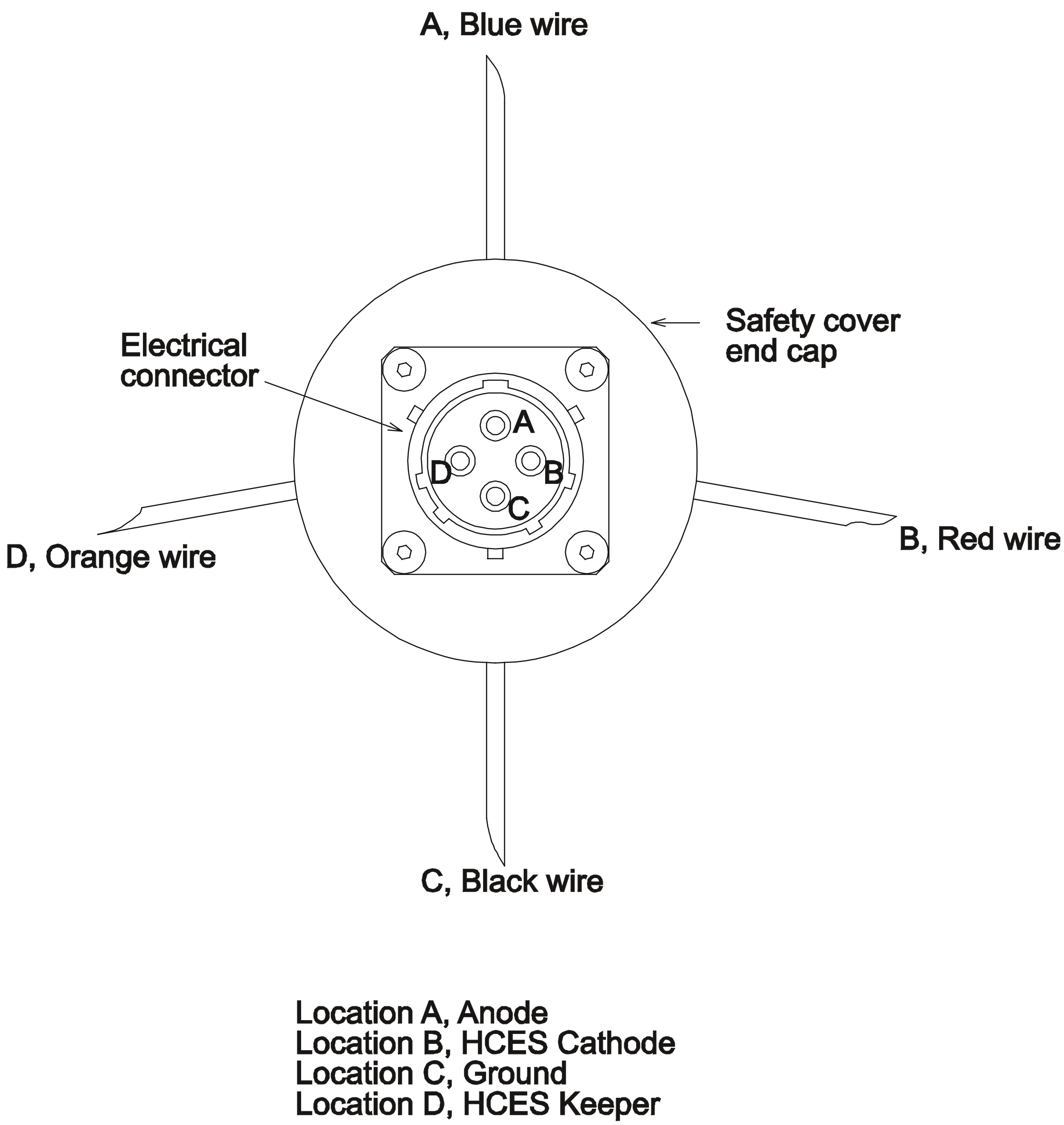


Fig. 2-7 Operating cable electrical connector.

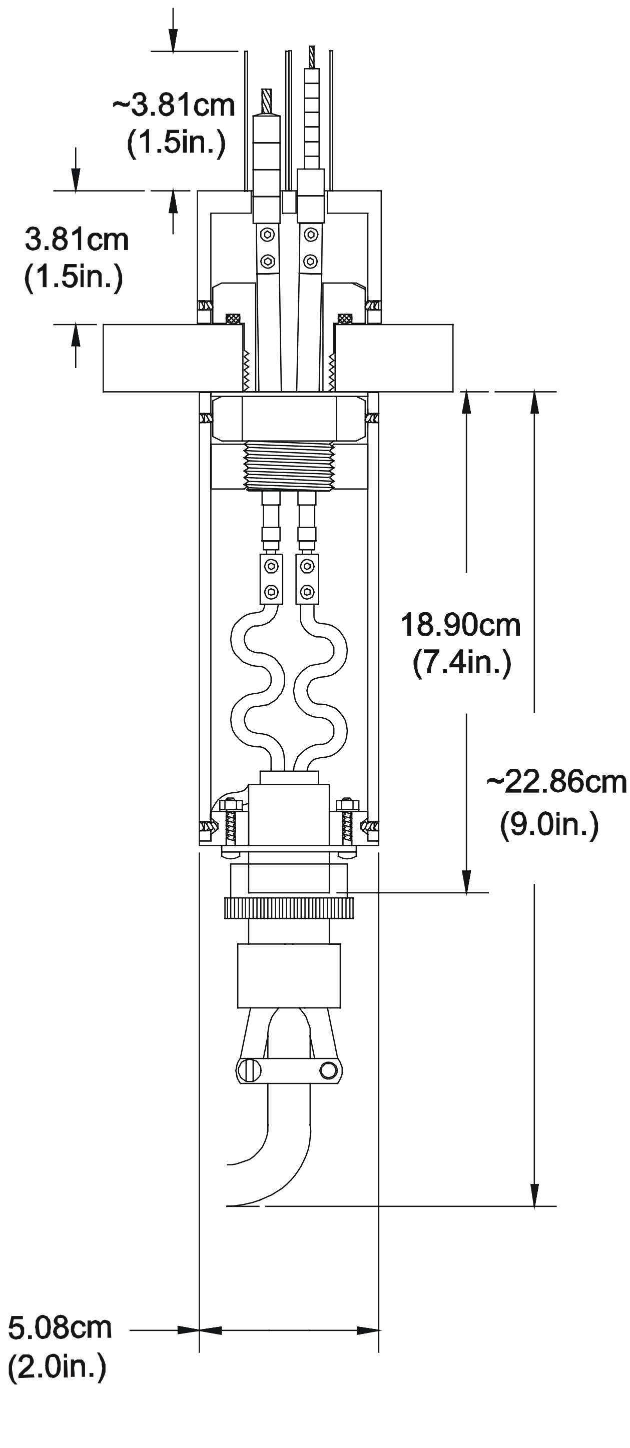


Fig. 2-8 Electrical feedthrough dimensions.

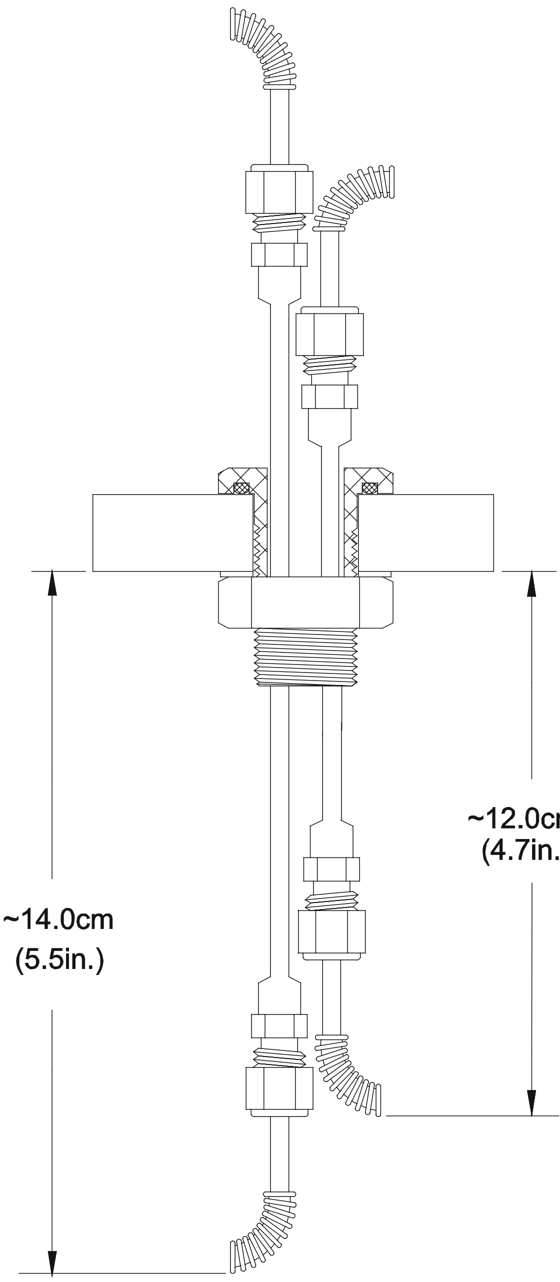


Fig. 2-9 Gas feedthrough dimensions.

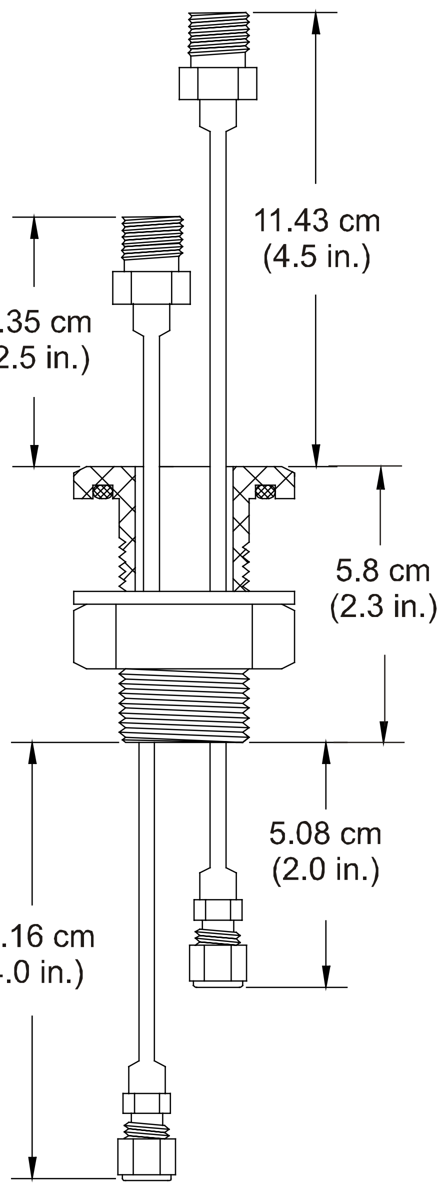


Fig. 2-10 Water feedthrough dimensions.

3 APPLICATION CONSIDERATIONS

3.1 Coverage Calculations

The ion beam profiles shown in Section 6 can be used to determine coverage. For source-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 $mA\text{-}sec/cm^2$ should be adequate to remove such contamination. In other words, an ion bombardment of one mA/cm^2 could be continued for one second, or one of 0.01 mA/cm^2 could be continued for 100 seconds.

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

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 pumpdown 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 section should be adequate for a general understanding of the operation of the EH2000-HC Ion Source. More detailed information on the controller is presented in the manual for the controller.

4.1 Schematic Diagram

Operation of the EH2000-HC Ion Source is described in summary form, it can be generally understood by reference to the block diagram of Fig. 4-1. Operation of the hollow cathode starts with argon introduced through the end of the hollow cathode tip. The keeper controller generates a high voltage between the cathode tip and the keeper, which starts a discharge. The discharge increases the temperature for operation. At the point of discharge, the hollow cathode has been started which reduces the voltage and increases the current. The low voltage maintains the discharge. After the hollow cathode has been started, an emission is established by the bias controller.

A gas flow is introduced into the EH2000 and voltage is then applied to the discharge or anode 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 neutral 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 near the anode 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 10.

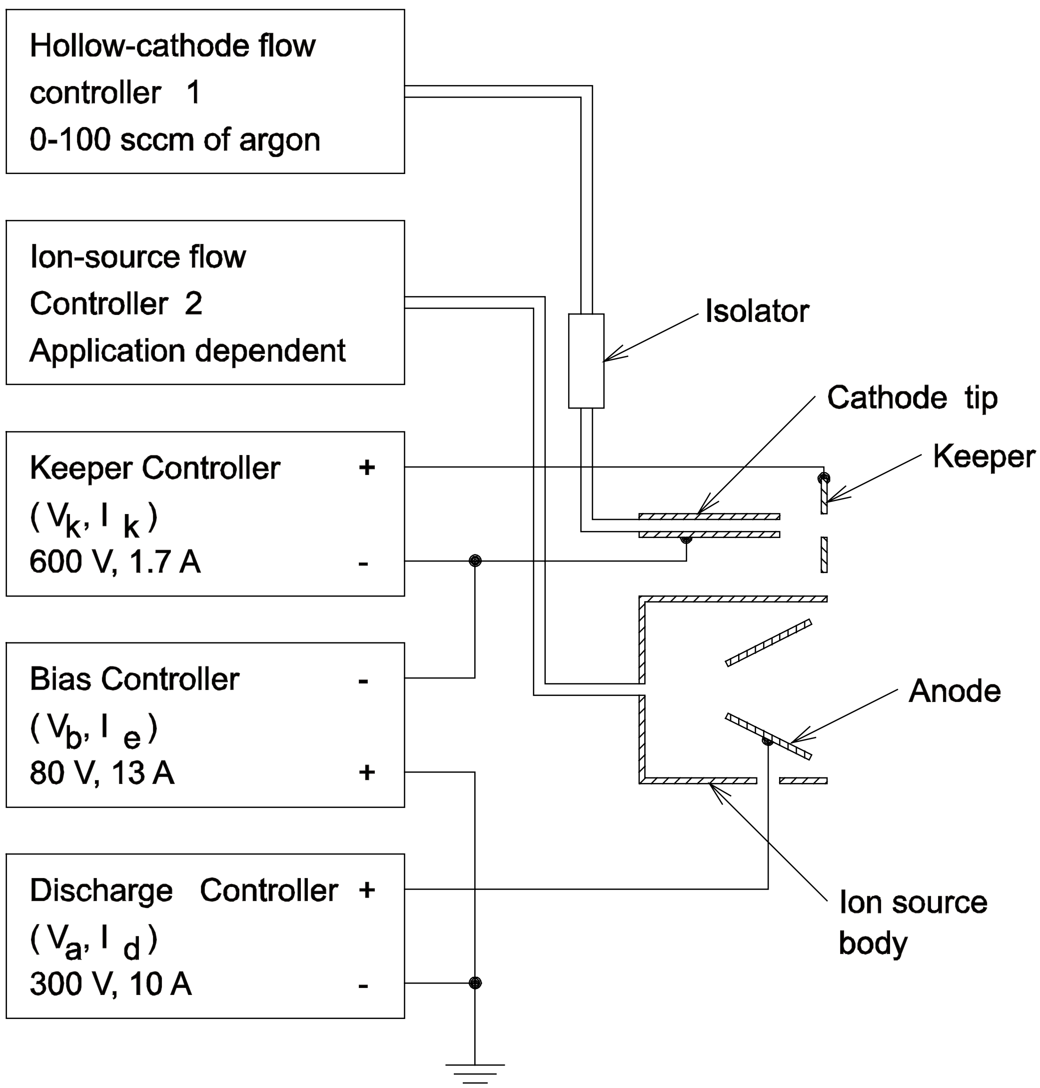


Fig. 4-1 Schematic diagram of the EH2000 ion source with the hollow cathode electron source.

5 OPERATION

Operation of the EH2000 ion source can be accomplished with the use of the following information. Operating parameters for the ion source can be found in the Characteristics section 6 of this manual. Additional information can be found in the Applications Consideration section 3 of this manual to assist with operation of the ion source. Prior to operating the EH2000 ion source, review all of the details outlined in the Inspection and Installation section 2 of this manual and the Installation section for the EH2000 Controller to insure that correct installation has been done, and all procedures have been followed. This section assumes that the operator has completed the Initial Operation procedures outlined in the EH2000 Controller manual and is familiar with controller operation.

5.1 Starting the HCES

Prior to starting the electron source an argon gas flow of 75 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. 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.

- Adjust the voltage and current controls on the Keeper Controller to maximum.
- Turn on the power to the Keeper Controller. The electron source should start and the keeper current should rise to approximately 1.6-1.8 A. The preferred keeper current is between 1.45 and 1.55 A.
- Adjust the current control until the keeper current is in the 1.45-1.55 A range. The voltage control will remain at maximum, or full clockwise during operation.
- Reduce the argon flow through the electron source to 10 sccm.
- Set the voltage control on the Bias Controller to maximum, fully clockwise.

- Turn on the power to the Bias Controller.

- Slowly increase the current control on the Bias Controller until the desired current is established. The bias current should always be equal to or slightly higher than the EH2000 discharge (Anode) current.

5.2 Starting the EH2000 Ion Source

- Turn on water supply to the anode.

- Adjust the gas flow into the ion source to a flow of 25-30 sccm.

- Adjust the voltage control to maximum.

- Adjust the current control to minimum.

- Turn on the power to the Discharge Controller.

- Slowly increase the current control, the discharge should start immediately. Continue to increase the current control until the desired discharge current is achieved.

- At this point the EH2000 discharge current and the electron source bias current should be equal.

- Adjust the discharge voltage to the desired operating value. Adjustment of the discharge voltage is accomplished with changes in gas flow. Increasing the gas flow will decrease the discharge voltage while decreasing the gas flow increases the discharge voltage.

5.3 Adjustments

Once the electron source and ion source are operating, slight adjustments may be needed to achieve the desired operating conditions.

6 CHARACTERISTICS

This section includes typical performance characteristics for a KRI END-HALL 2000 ion source with the KRI SHC-2000 hollow cathode electron source. The data provided should be used as a guide for operating parameters of the ion source and the electron 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 Maintenance section 7 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 EH-2000 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 clausing 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 $P_{chamber}$ 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.

6.4 Ion Beam Current and Energy

The ion beam current and energy for the KRI EH-2000 ion source is shown in Figs. 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 Fig. 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.

6.5 Ion Beam Profiles

Figure 6-9 is a sample retarding potential probe analysis curve on axis of the ion source. The mean energy shown in Fig. 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.

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.). Fig. 6-10 illustrates both target configurations. Argon profiles can be found in Figs. 6-11 through 6-16. Oxygen and Nitrogen profiles are included in Figs. 6-17 through 6-28. The ion current density would vary inversely as the square of the distance at other target distances.

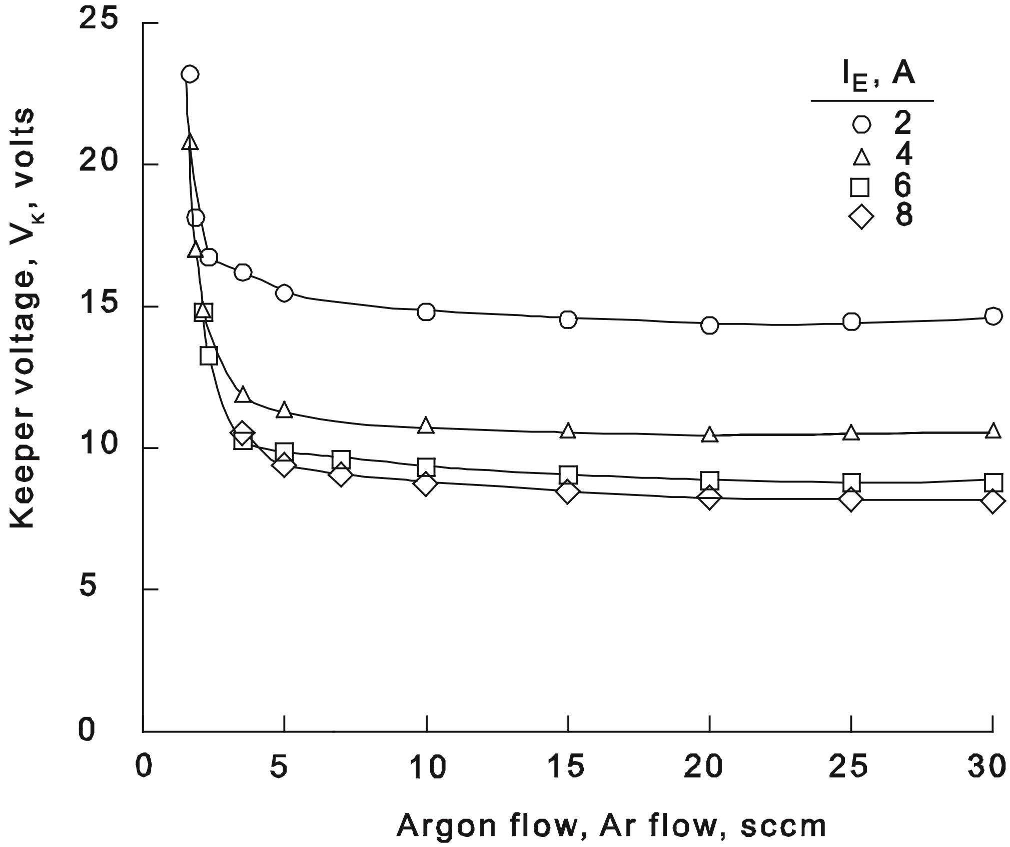


Fig. 6-1 Variation in hollow cathode keeper voltage with argon gas flow for various emission currents.

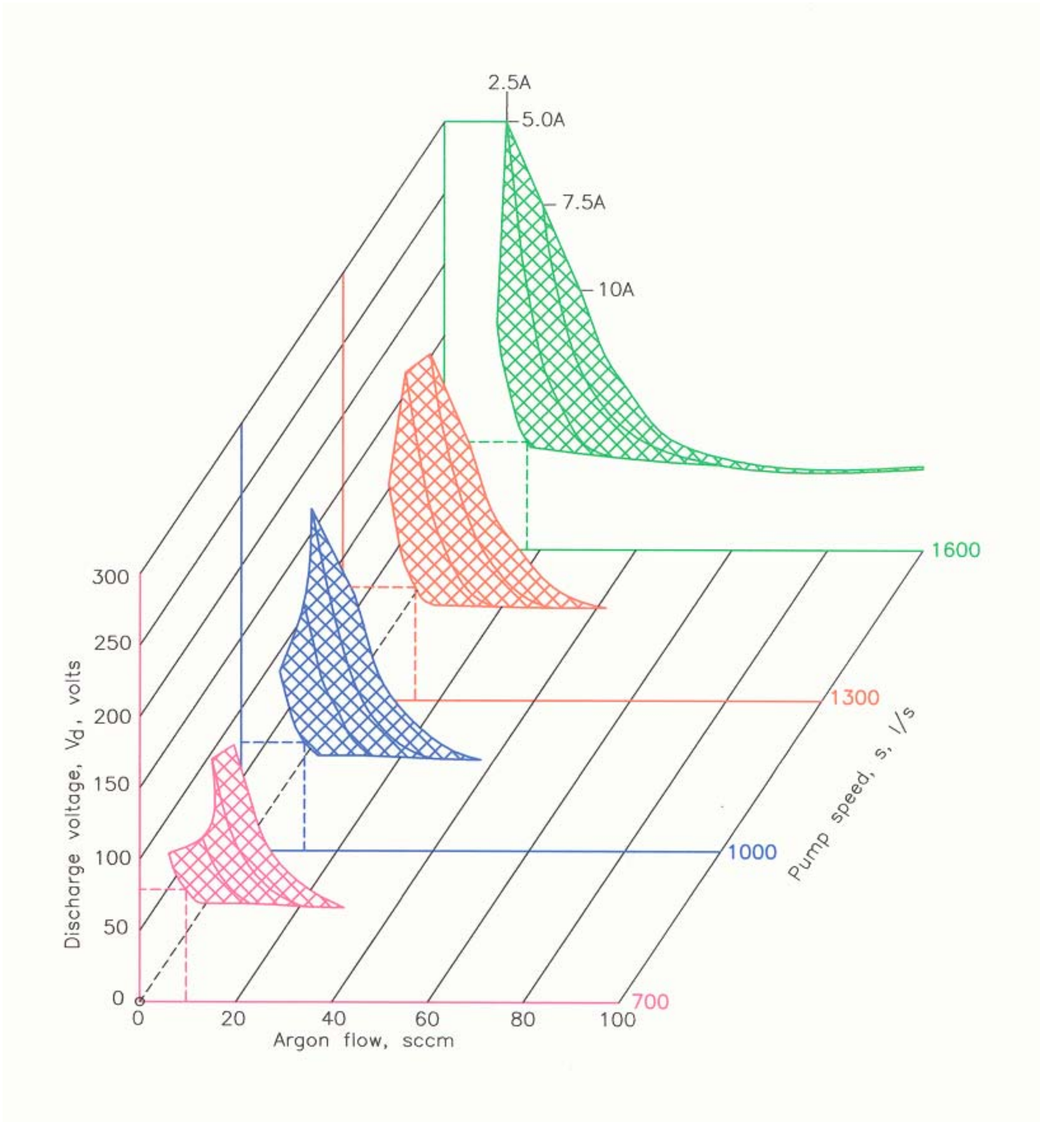


Fig. 6-2 Range of operation for the KRI End-Hall 2000 Ion Source at various pump speeds, using argon.

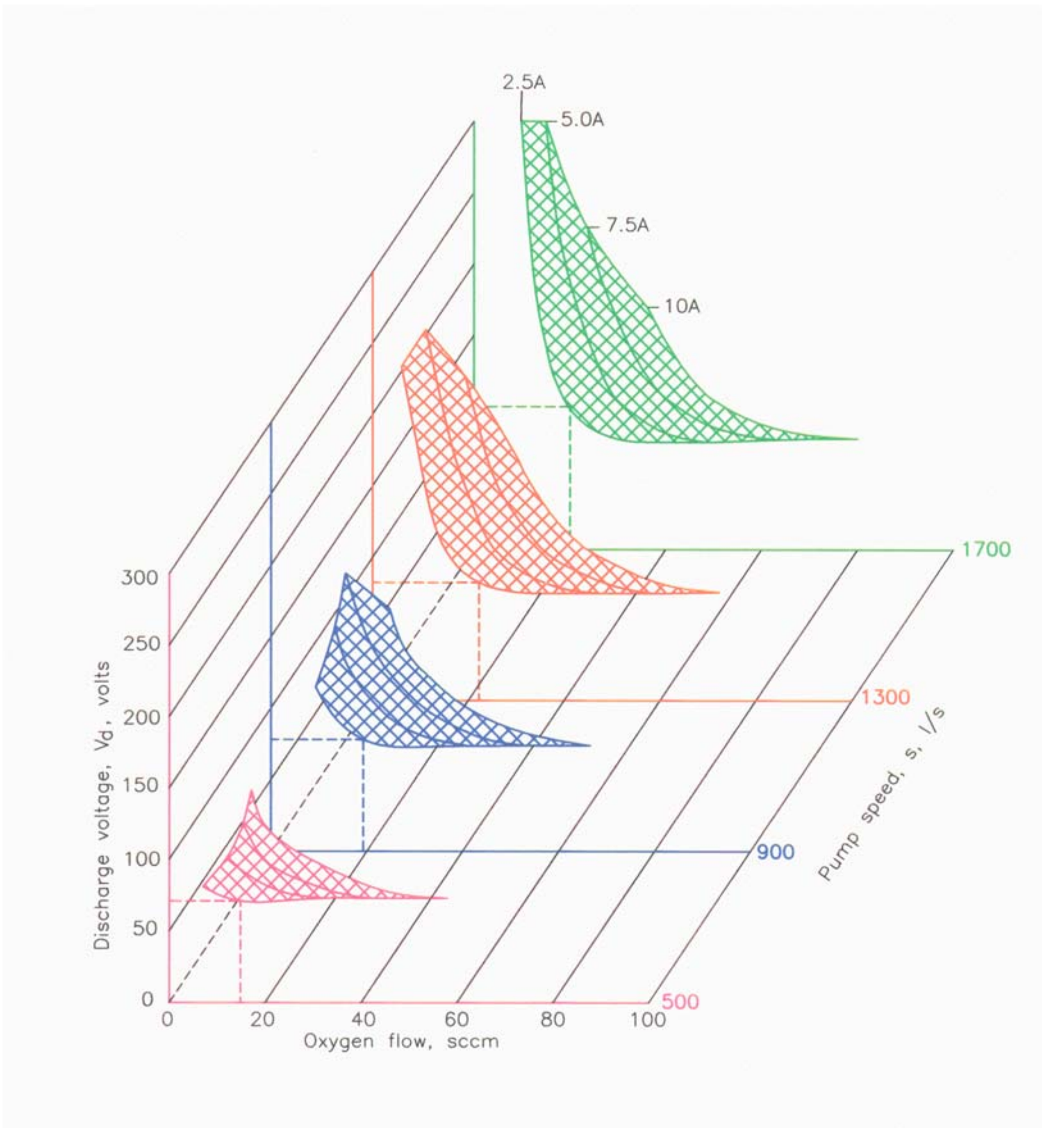


Fig. 6-3 Range of operation for the KRI End-Hall 2000 Ion Source at various pump speeds, using oxygen.

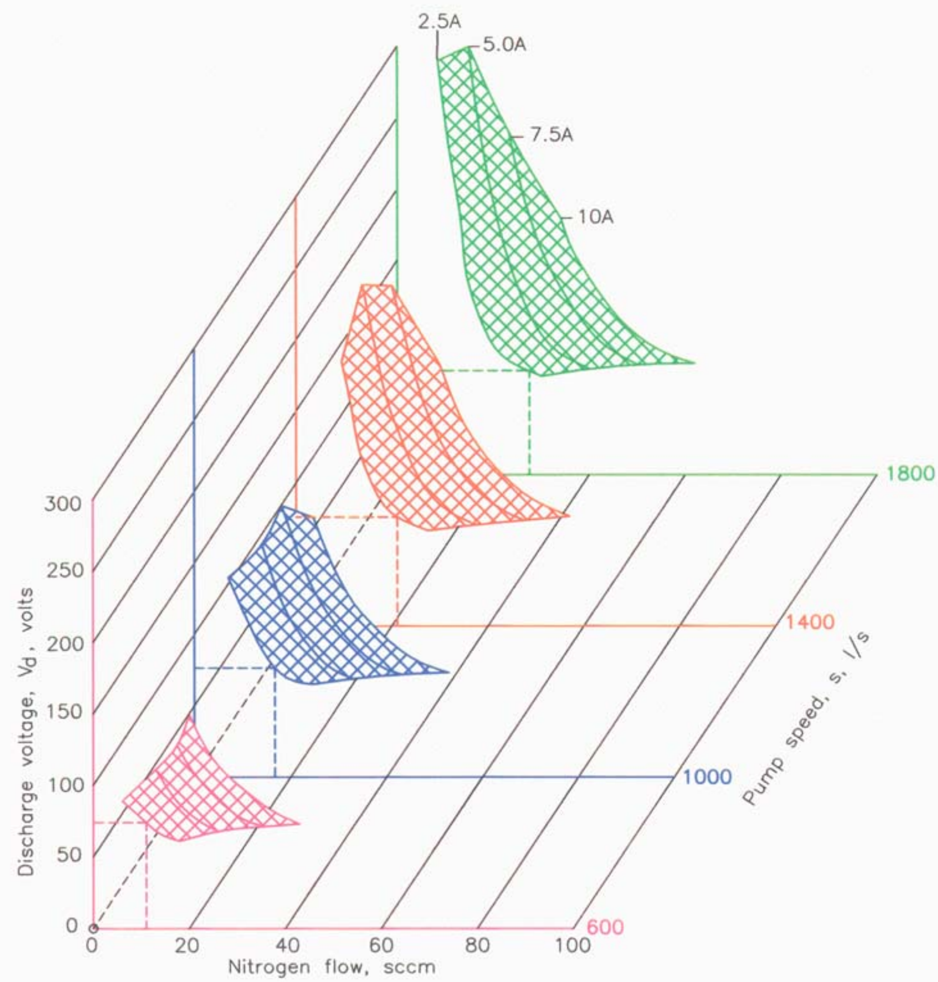


Fig. 6-4 Range of operation for the KRI End-Hall 2000 Ion Source at various pump speeds, using nitrogen.

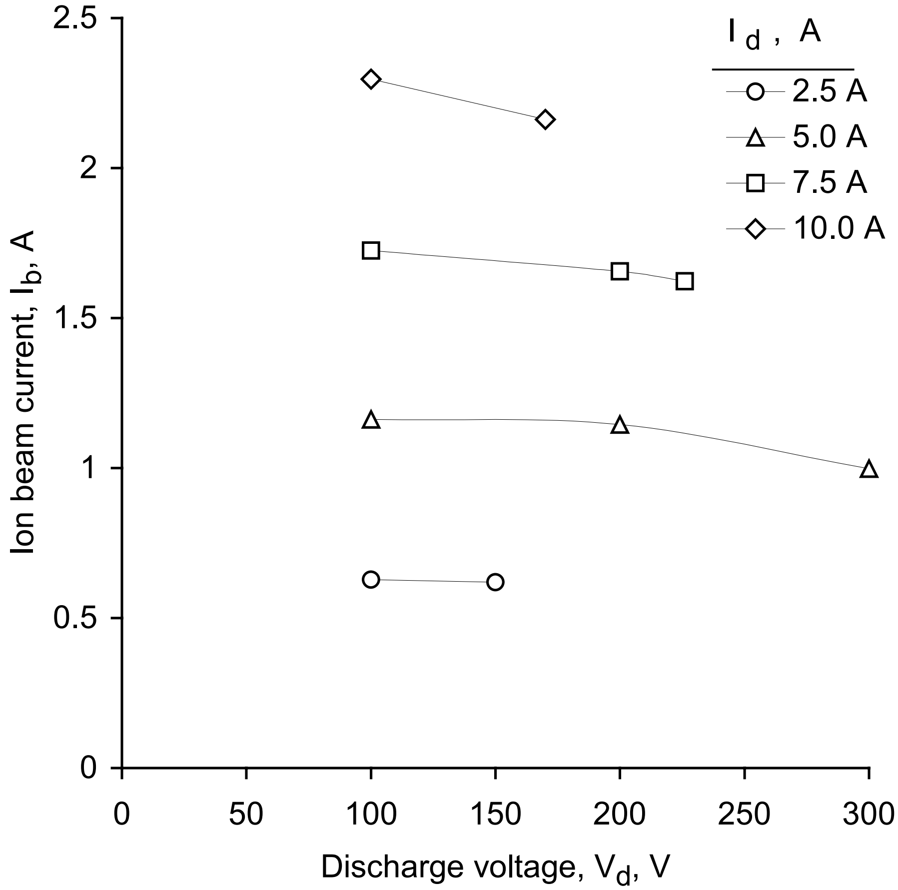


Fig. 6-5 Variation of ion beam current with discharge voltage at various discharge currents, using argon.

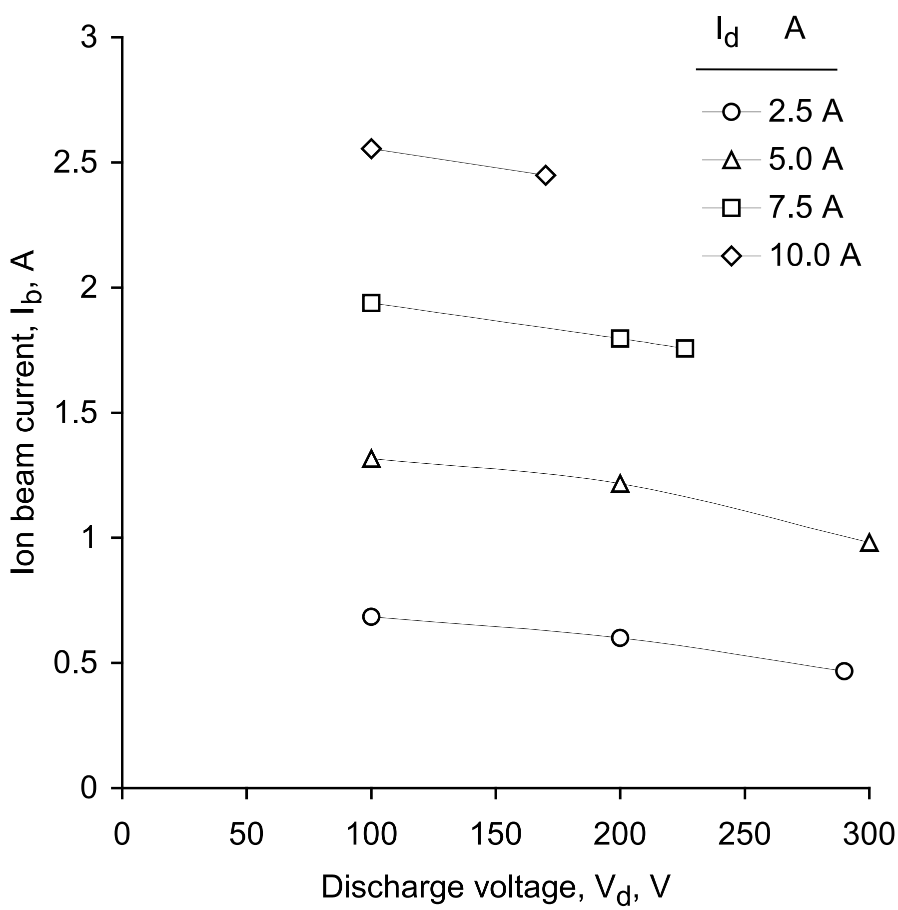


Fig. 6-6 Variation of ion beam current with discharge voltage at various discharge currents, using oxygen.

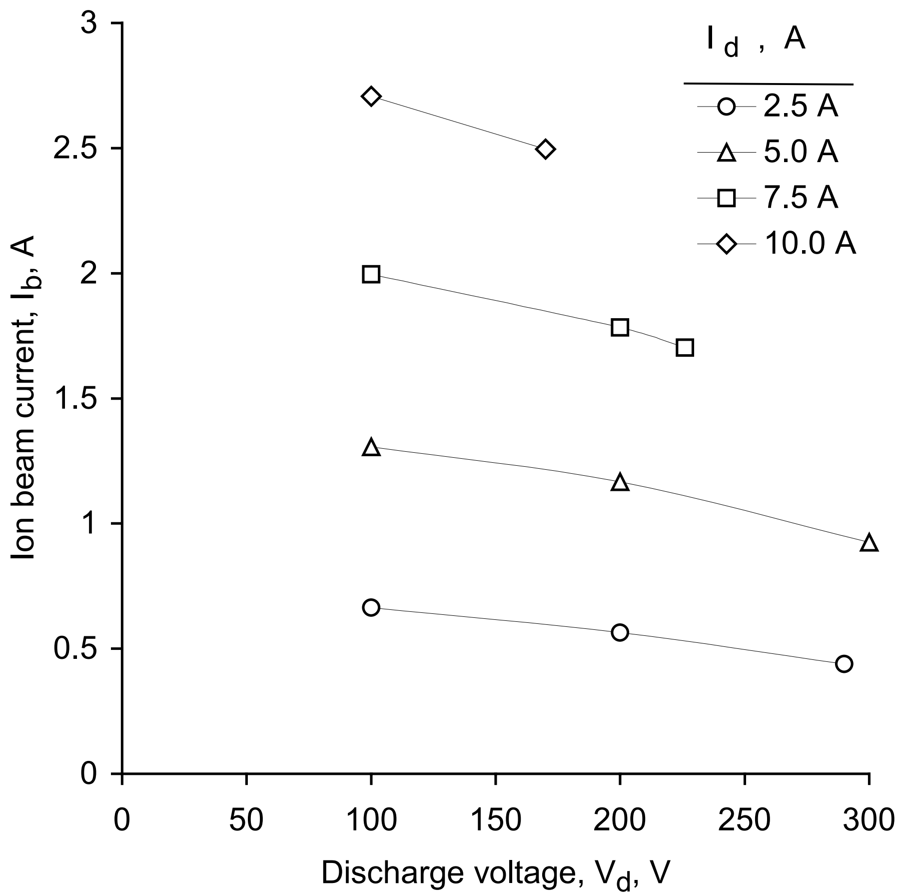


Fig. 6-7 Variation of ion beam current with discharge voltage at various discharge currents, using nitrogen.

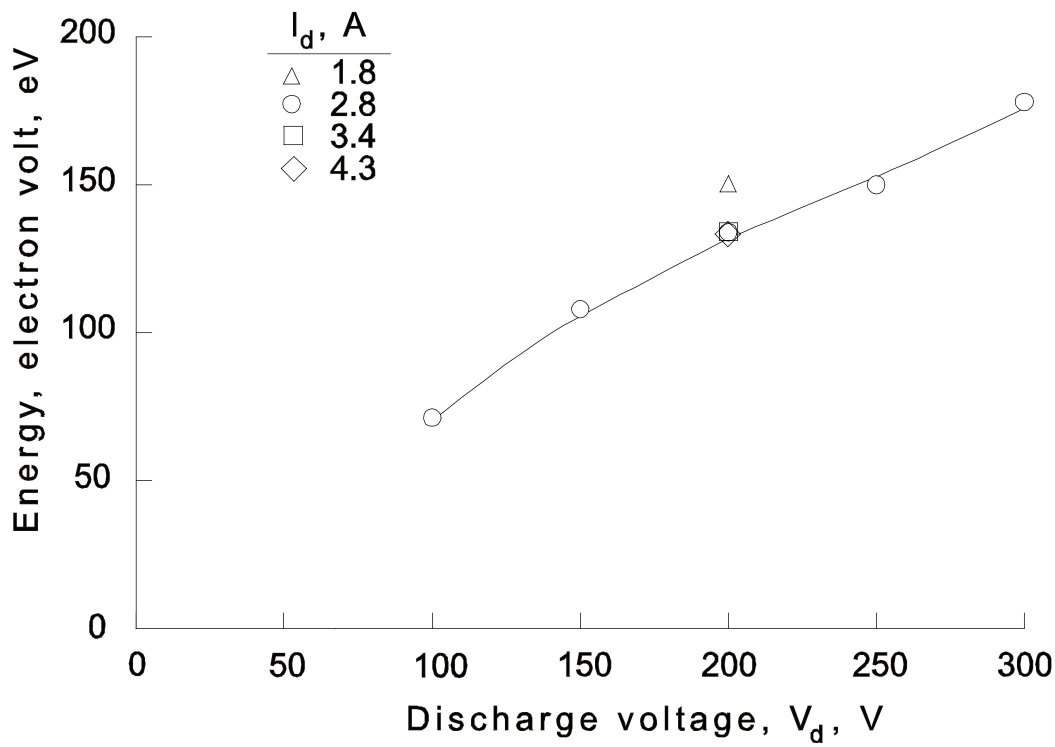


Fig. 6-8 Mean ion energy with variation in discharge voltage.

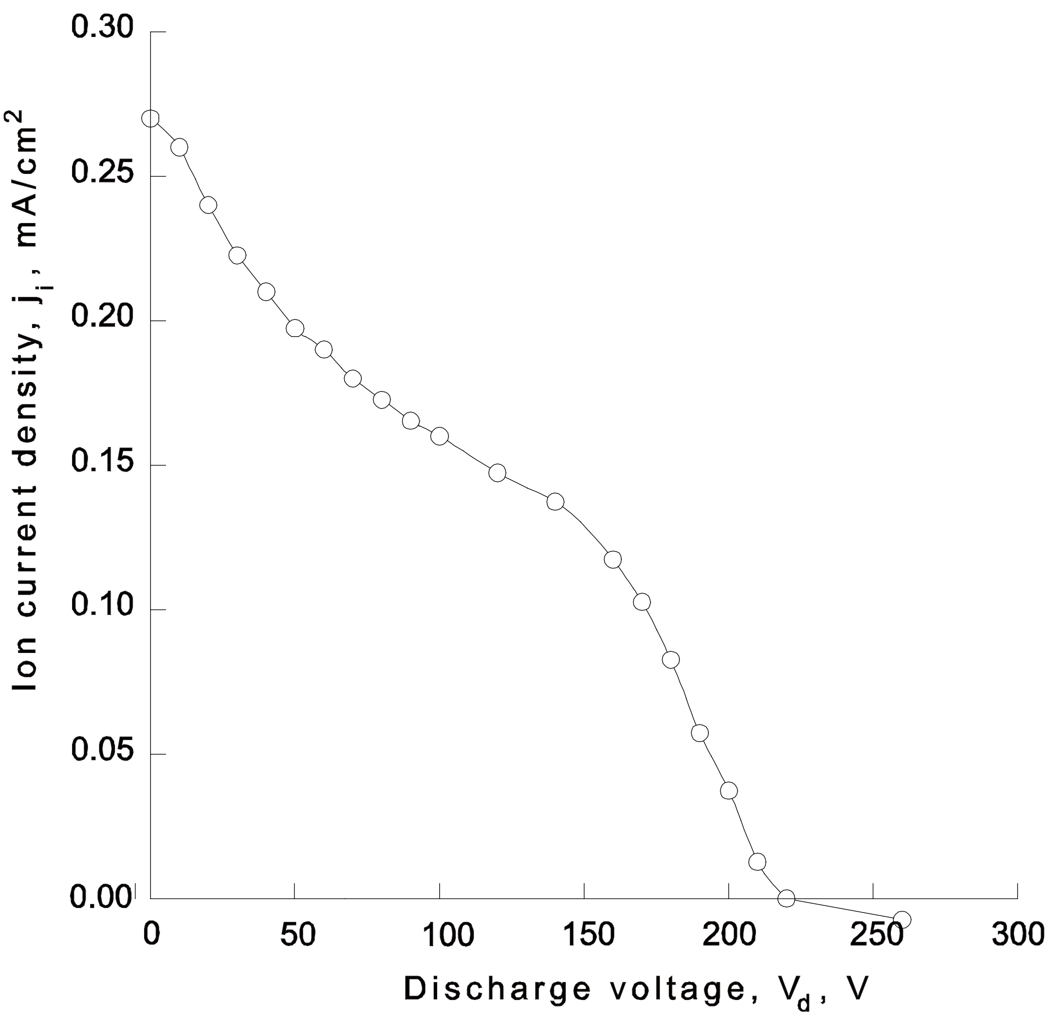


Fig. 6-9 Retarding potential probe analysis of the ion beam at a discharge voltage and current of 200 V and 2.8 A.

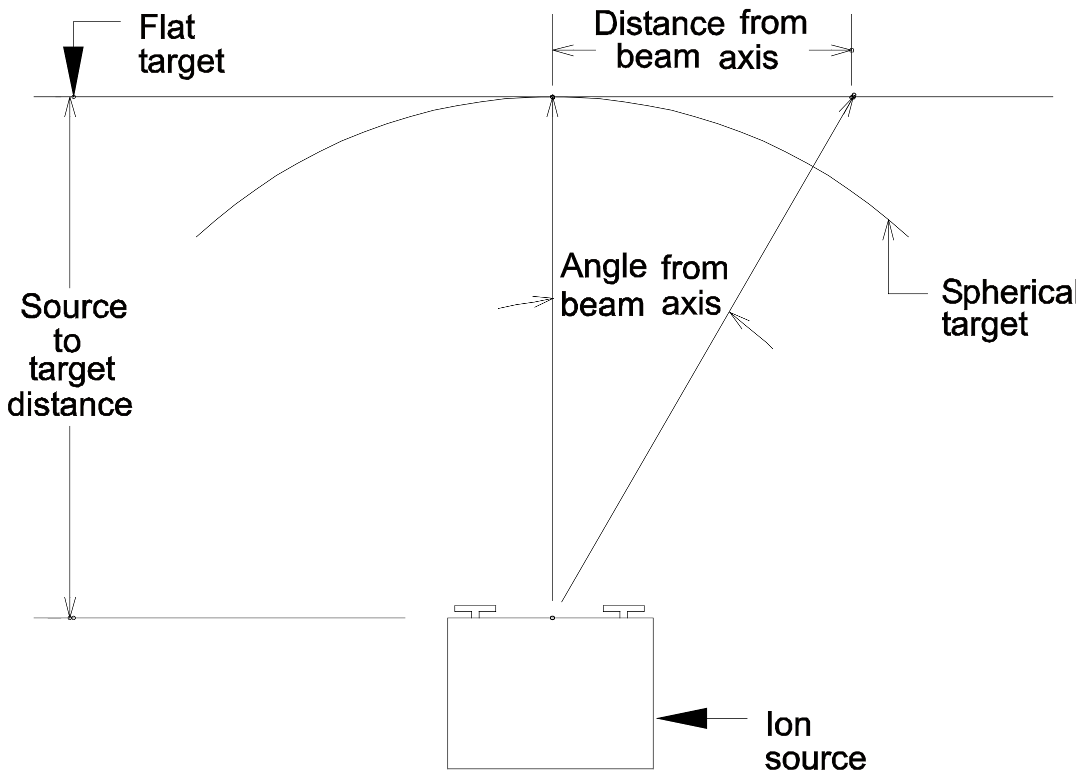


Fig. 6-10 Spherical and flat target configurations.

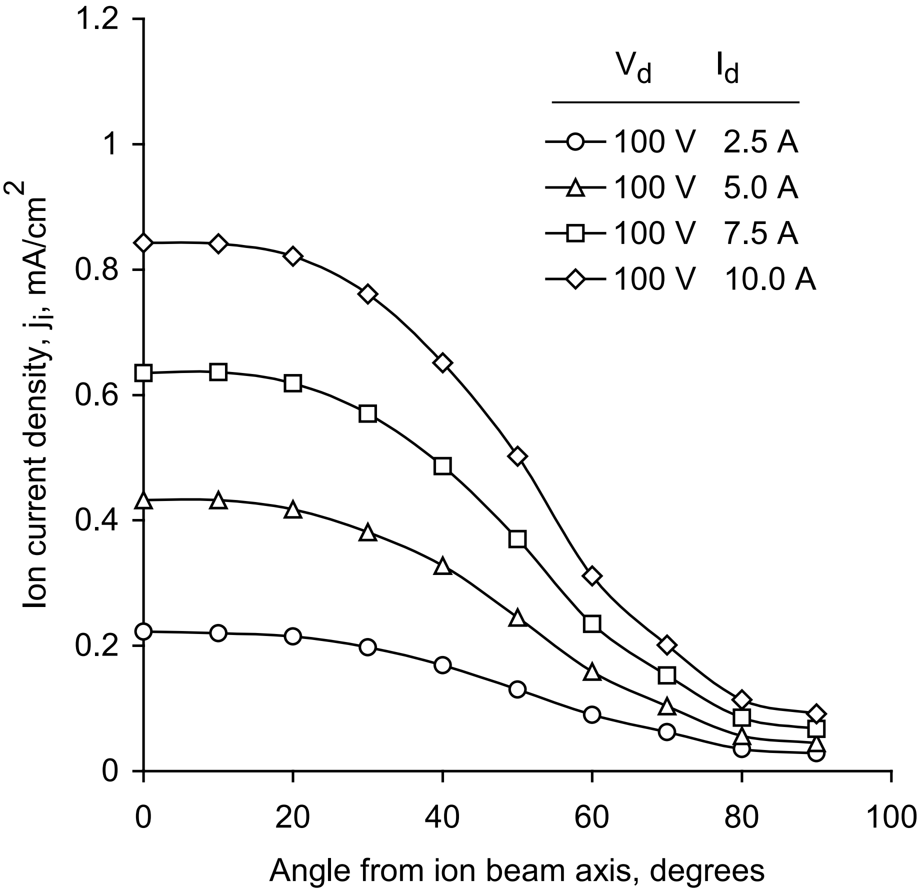


Fig. 6-11 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

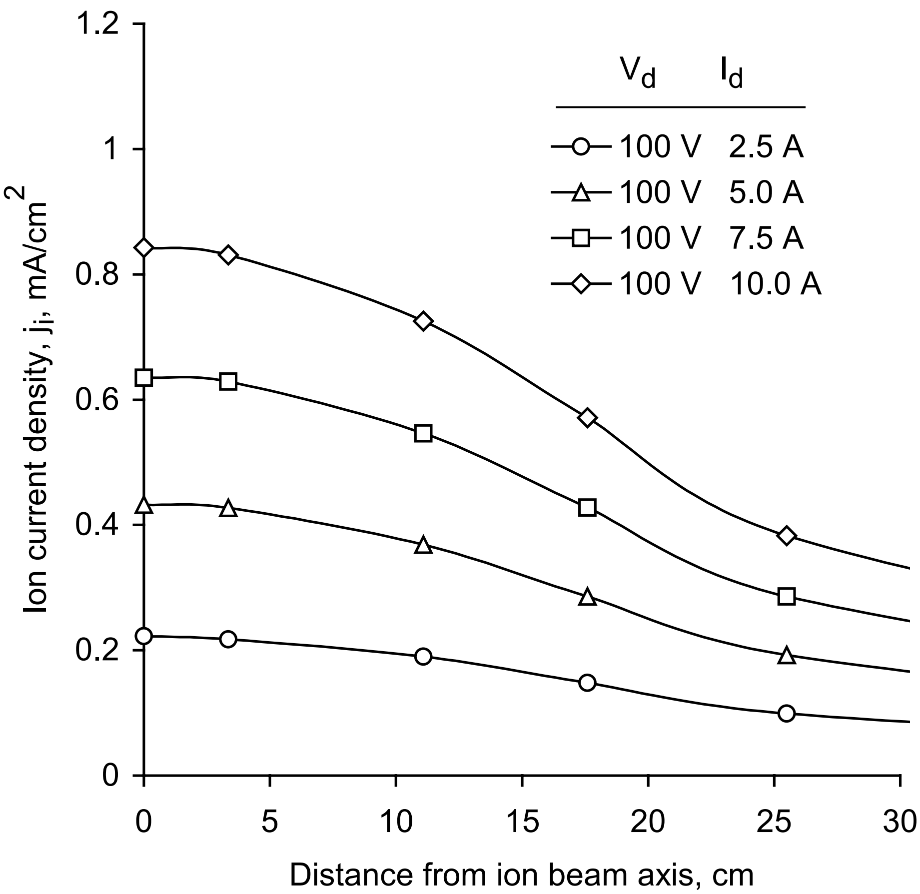


Fig. 6-12 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon.

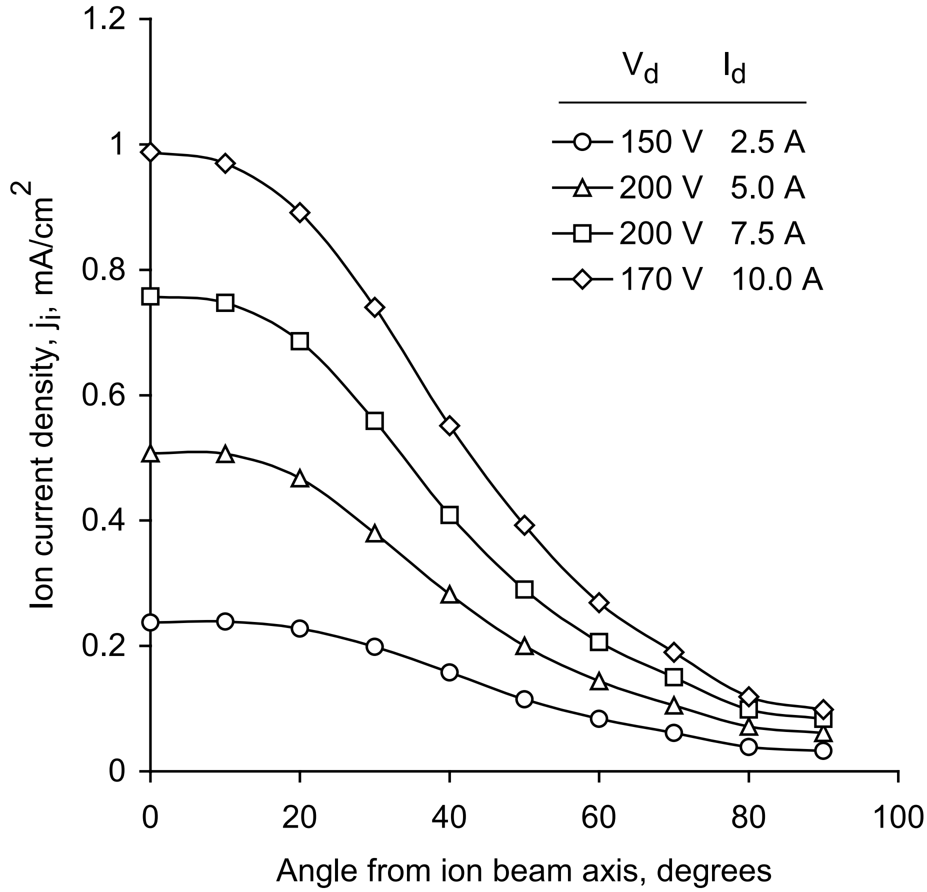


Fig. 6-13 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

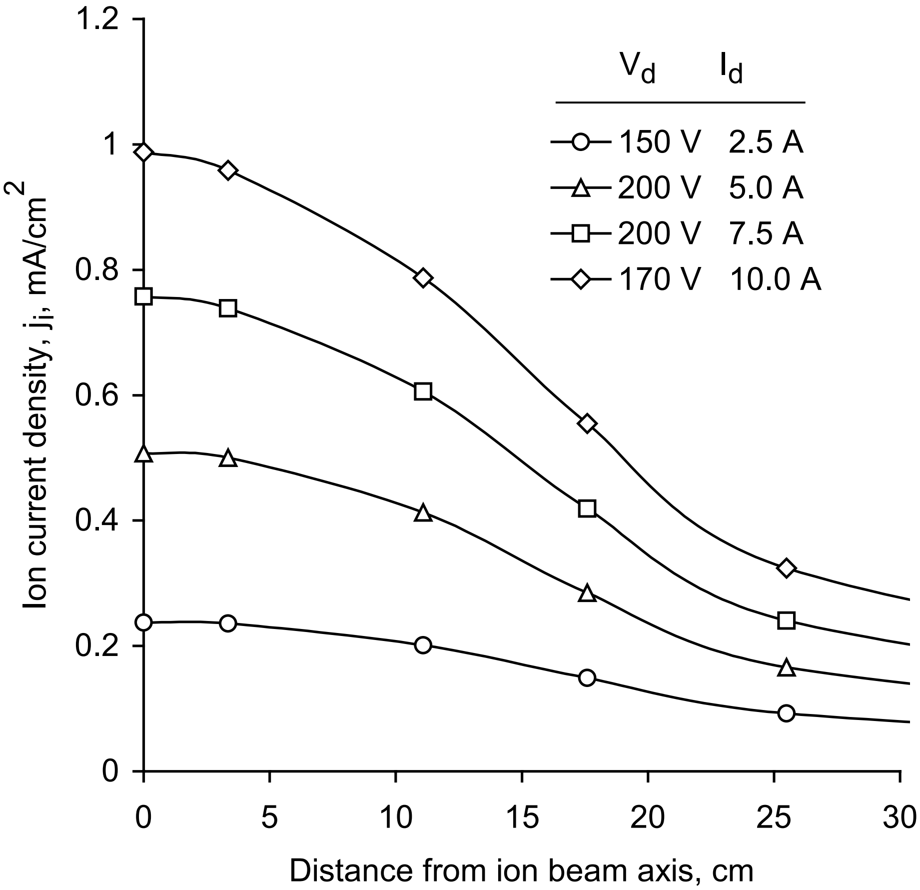


Fig. 6-14 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon.

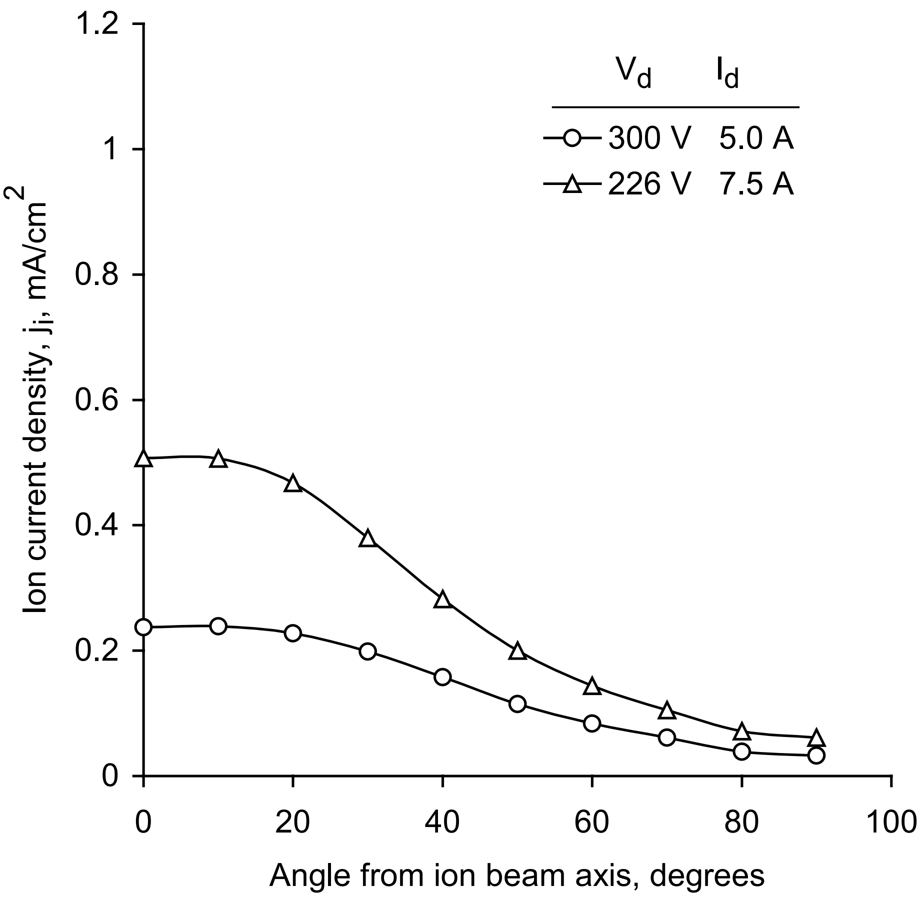


Fig. 6-15 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

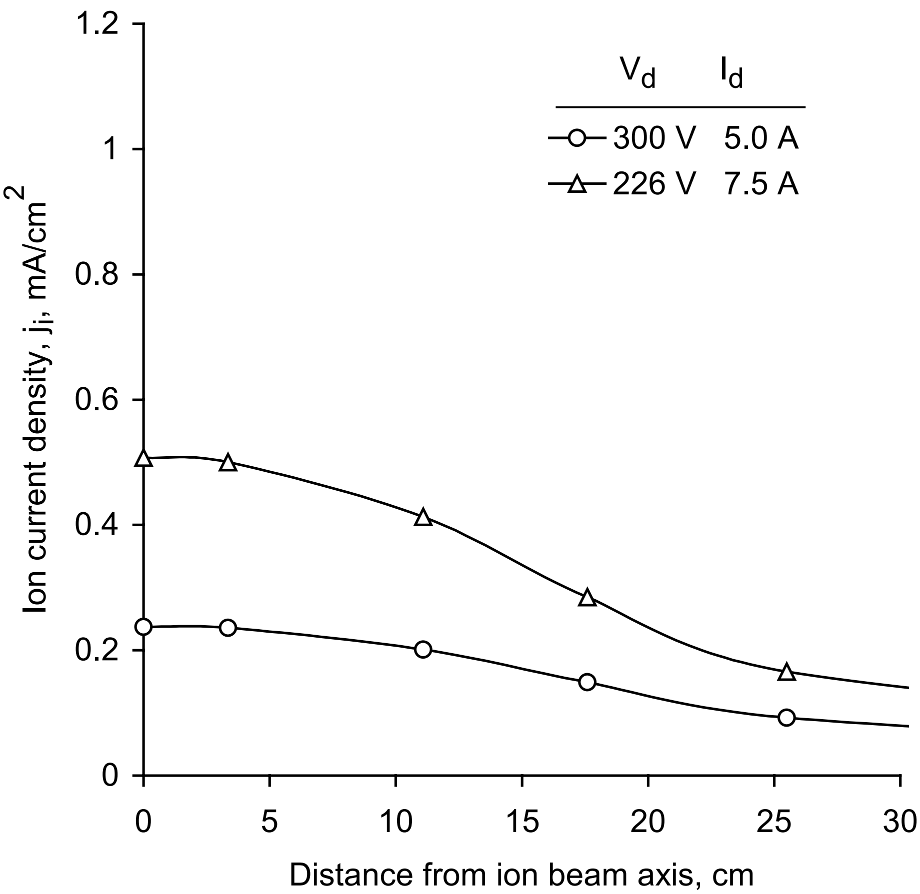


Fig. 6-16 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon

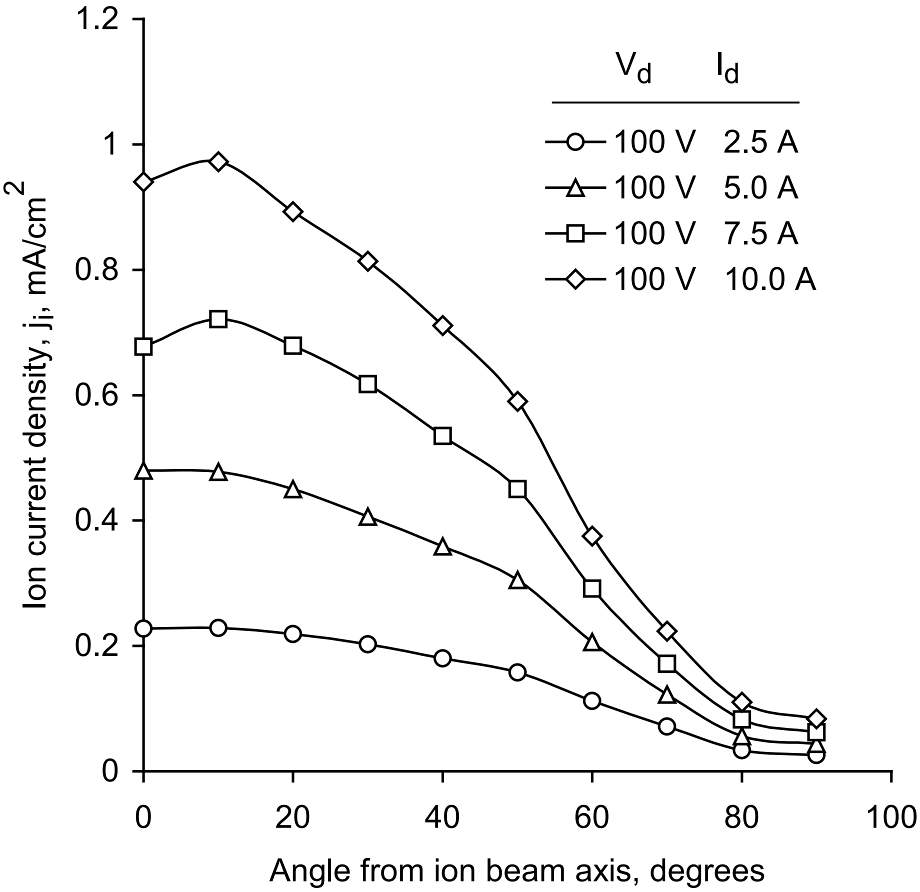


Fig. 6-17 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

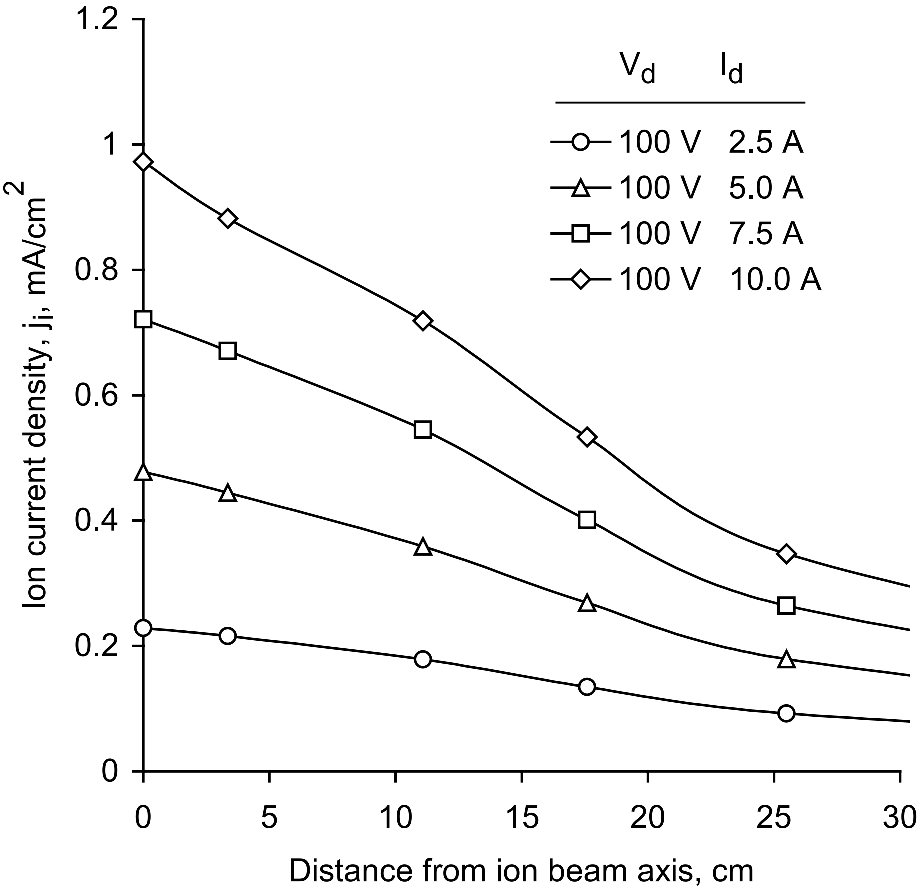


Fig. 6-18 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

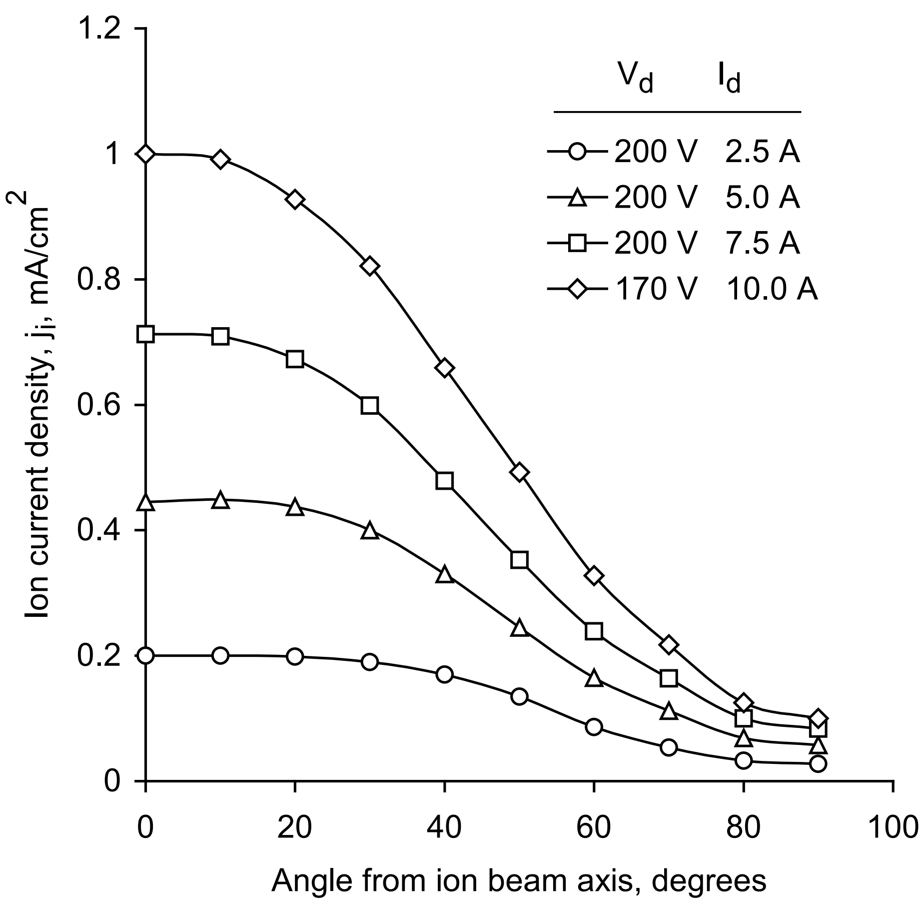


Fig. 6-19 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

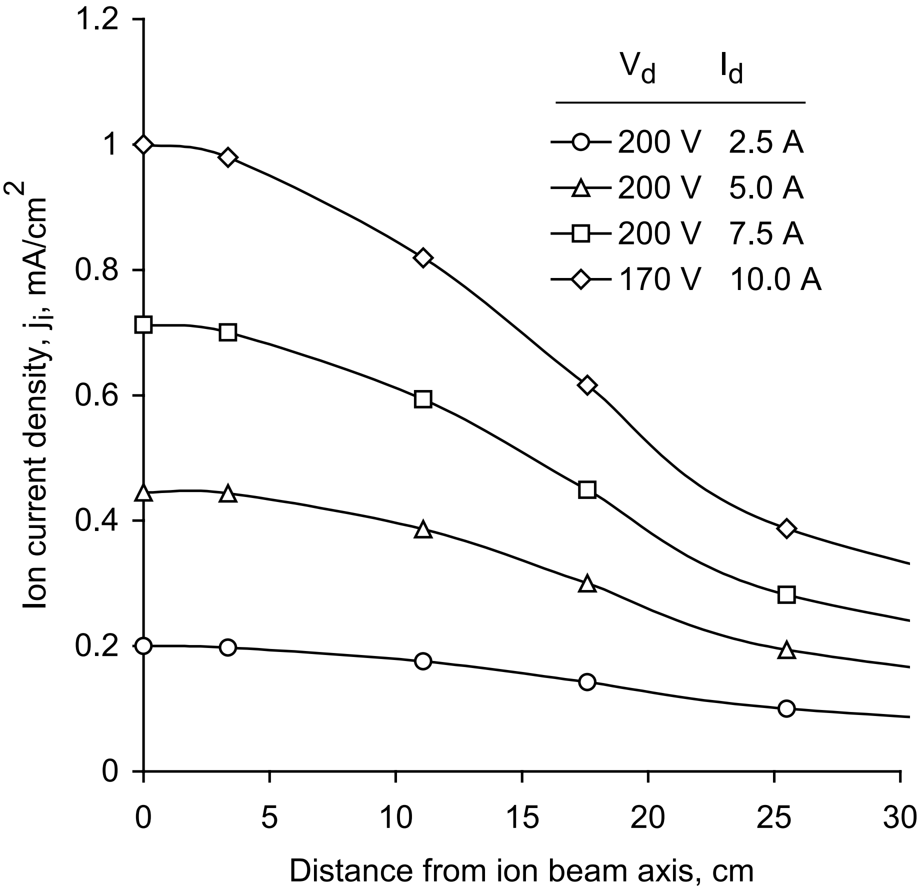


Fig. 6-20 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

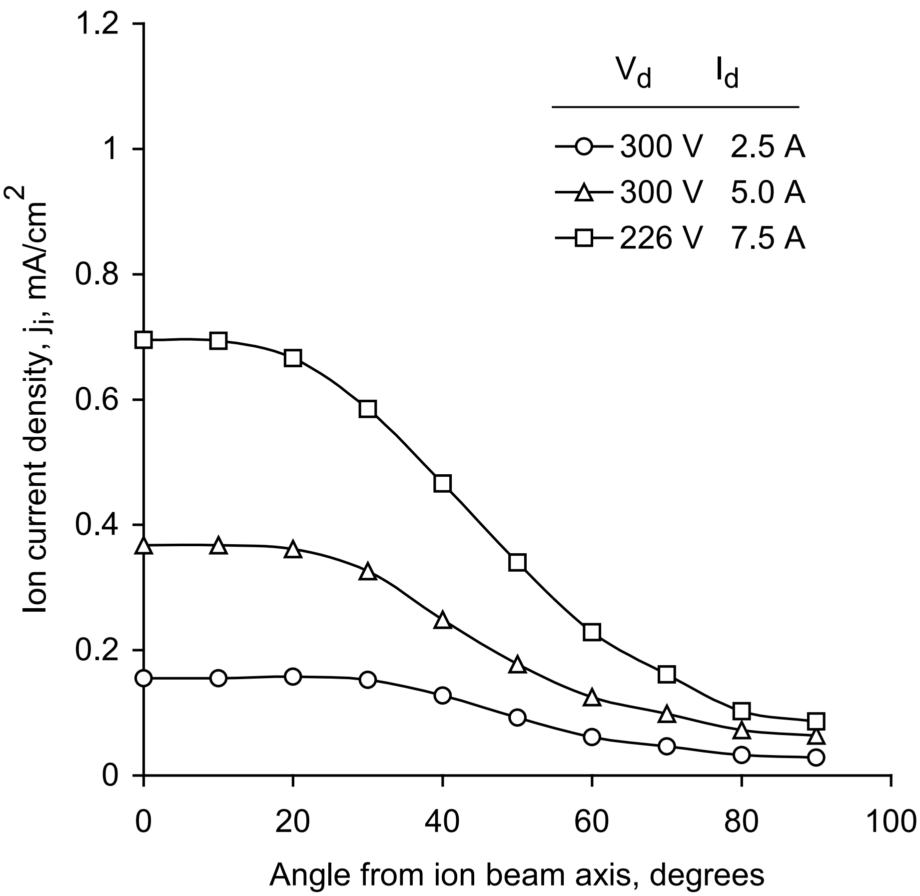


Fig. 6-21 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

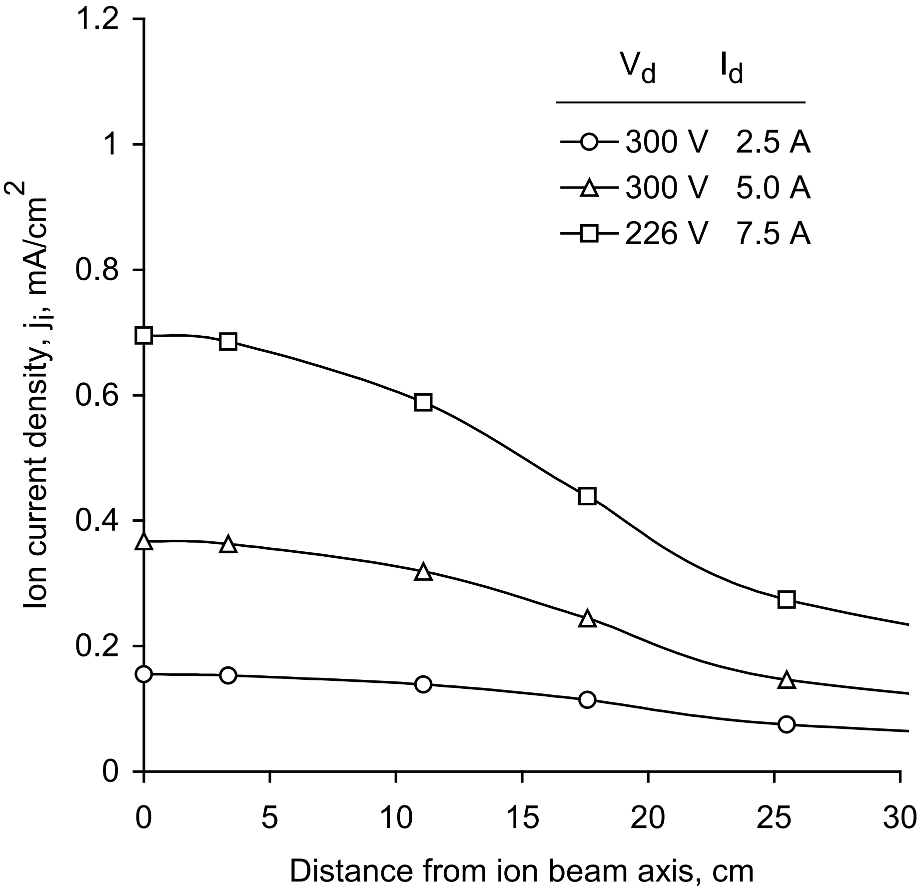


Fig. 6-22 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

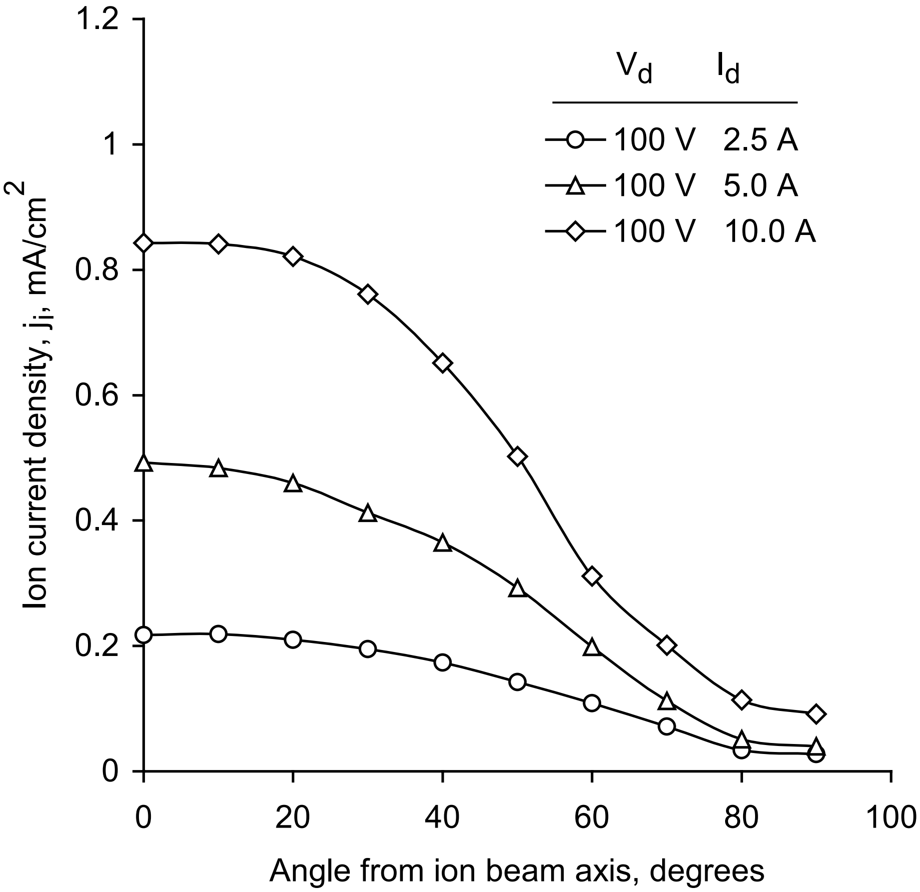


Fig. 6-23 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

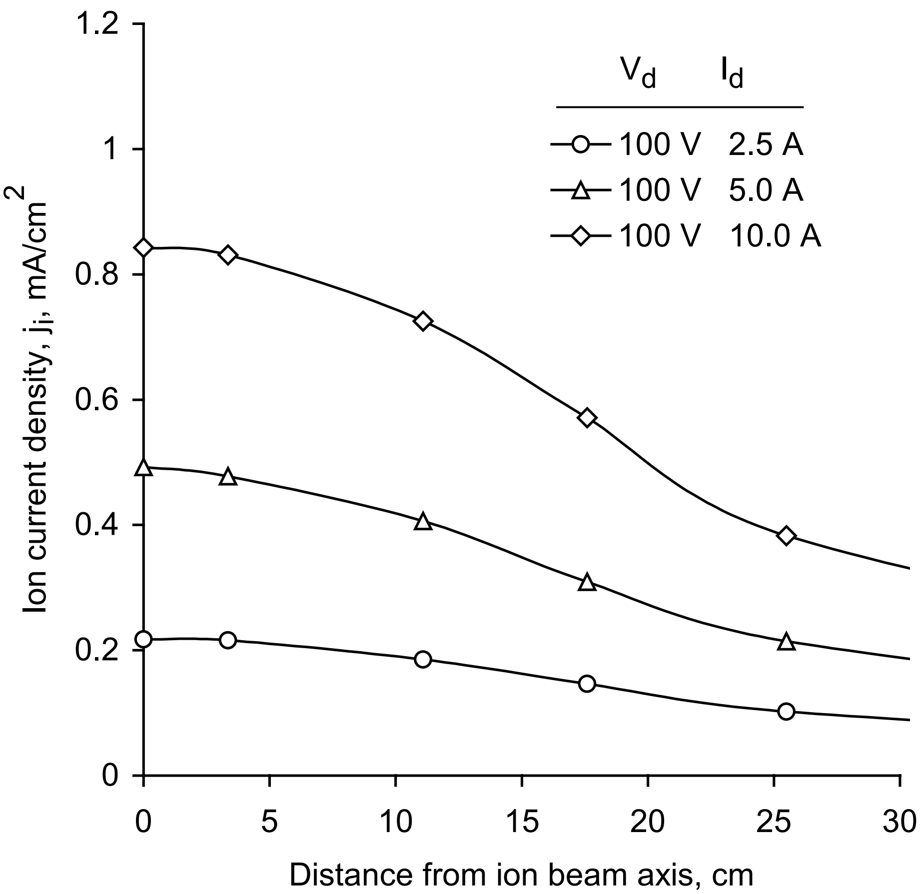


Fig. 6-24 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

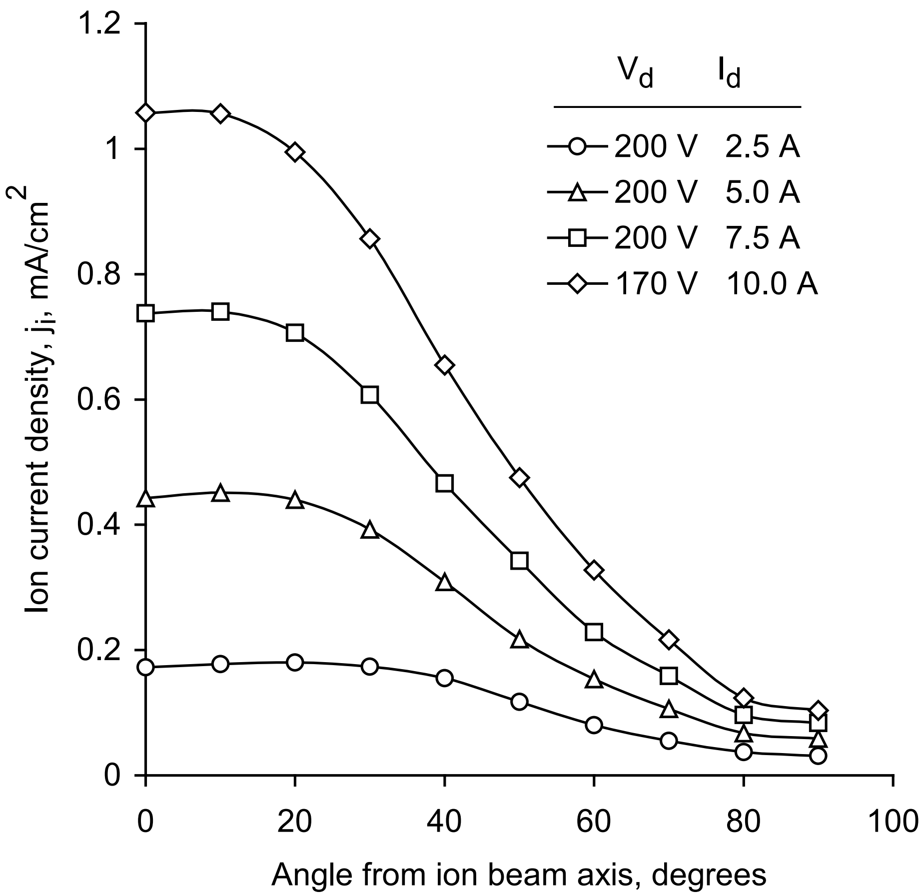


Fig. 6-25 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

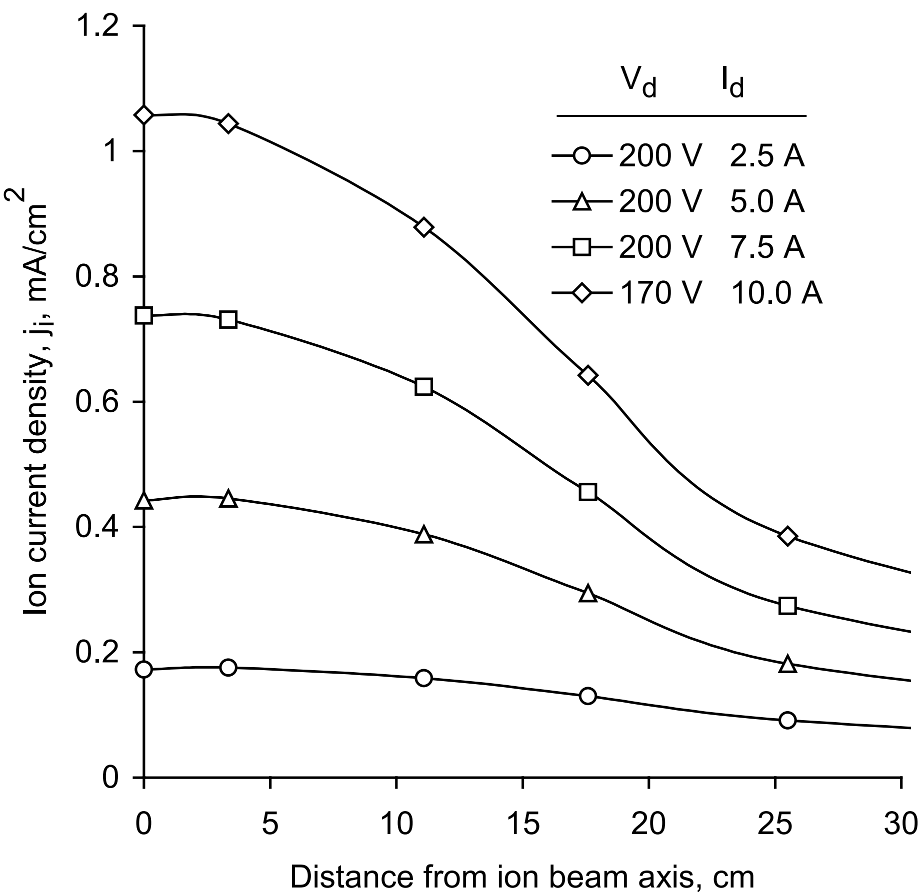


Fig. 6-26 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

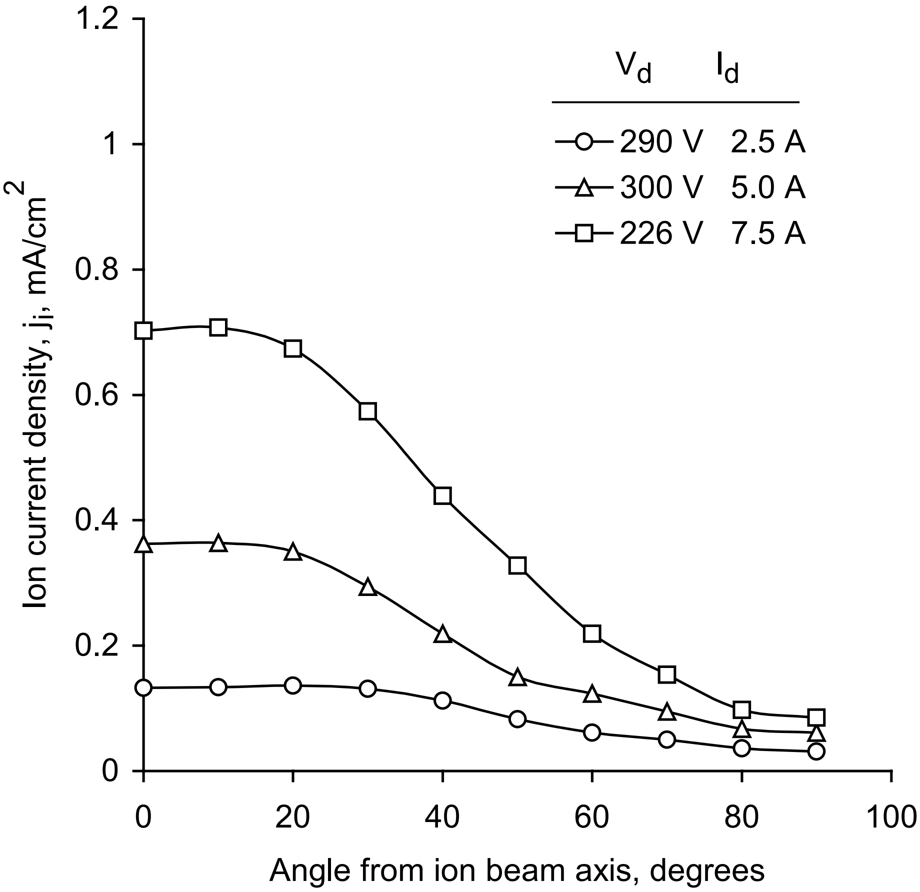


Fig. 6-27 Spherical ion current density profiles for the KRI End-Hall 2000 ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

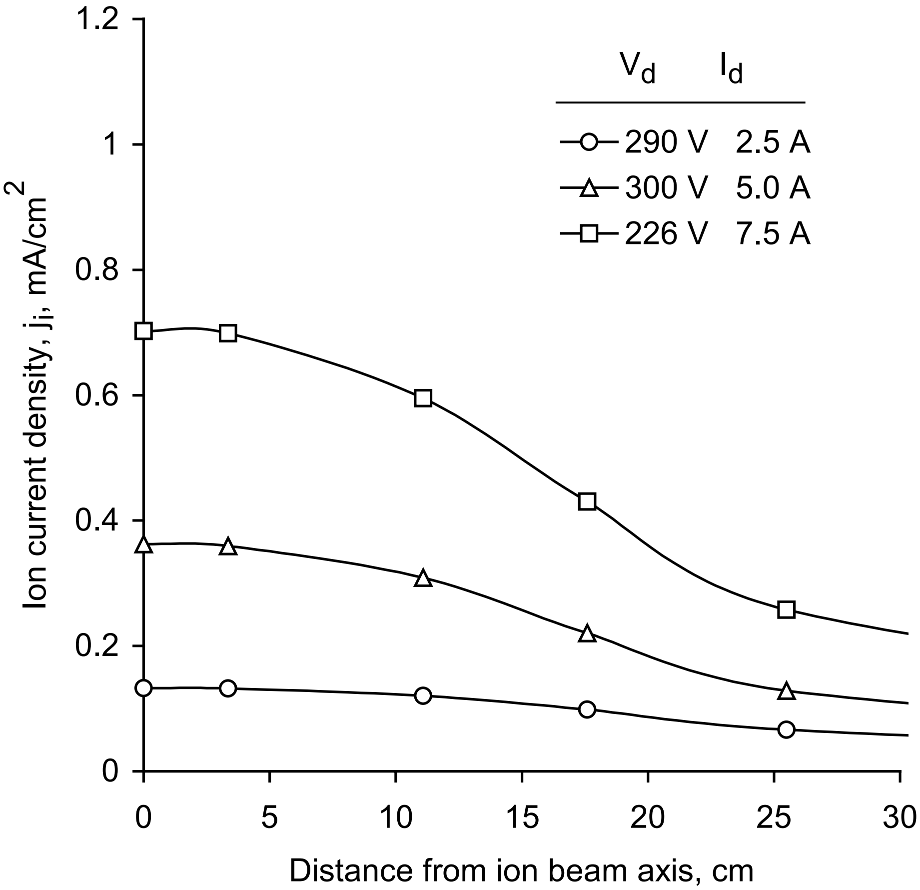


Fig. 6-28 Flat target ion current density profiles for the KRI End-Hall 2000 ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

7 MAINTENANCE

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

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

7.1 Gas Line or Gas Bottle Replacement

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, proceed with the following steps to help locate the problem.

7.2.1 Continuity Checks

- Check continuity of the electrical isolator between the two Swagelok™ fittings on each end (Fig. 7-1). If less than infinite resistance is present replace the electrical isolator.

- Check continuity between the hollow cathode body and the hollow cathode bracket. If less than infinite resistance is present the 10-32M or 10-32F insulators located between the body and bracket maybe coated or broken (Fig. 7-2).

- Check continuity between the cathode body and gas line (Fig. 7-2). If less than infinite resistance is present, either the SHC-03 insulators are coated or the gas line is in contact with the cathode body.

7.2.2 Disassembly Separate the hollow cathode from ion the source by removing the acorn nut that secures the hollow cathode bracket to the front plate (Fig. 7-3). Next unthread the 1/4 inch Swagelok™ nut located on the feedthrough end of the hollow cathode gas insulator (Fig. 7-3), unthread the 10-32 by 5/8 inch bolts that hold the body to the bracket and place the hollow cathode on a safe clean work surface.

Proceed with disassembly by taking the two 4-40 screws, washers and nuts from each end of the cathode that secure the main retainer and the keeper retainer to the body (Fig. 7-4). After the keeper retainer has be removed the keeper may now be removed from the body (Fig. 7-5).

Next the cathode and the two insulators may be removed from the bottom of the body (Fig. 7-6). Inspect the top insulator for coating and replace if necessary. Inspect the inner diameter of the keeper. If the ID is larger than 0.356 cm (0.14 inches), replace with a new keeper.

Make a general inspection of the cathode tip. If the quality of the tip appears to be poor such as; tantalum foil flaking or unwrapping, cathode hole becoming deeply concaved or holes through the side of the tube, a replacement cathode is required. Contact KRI for replacement parts.

7.2.3 Assembly Proceed with the following steps if replacement of the cathode is necessary and assuming the old cathode as been removed by following previously outlined instructions. **Gently** insert the cathode assembly, making sure the SHC-03 insulator fits around the end of the 1/16" Swagelok™ nut, into the body from the bottom (Fig. 7-7). It is important to assure a proper fit of the SHC-03 insulator into the inside of the body. Next make sure the bottom SHC-03 insulator is seated properly against the bottom 1/16" Swagelok™ nut and slide the main retainer against the insulator. Secure the main retainer to the body with the 4-40 screws, washers and nuts (Fig. 7-4). After these procedures have been carried out the main retainer should rest approximately halfway into the body; this will insure the proper fit for the new cathode (Fig. 7-8). If the main retainer doesn't rest inside the body reassemble until a proper fit is achieved.

Now that the new cathode is installed in the body it will now need to be aligned. Place the keeper into the top of the body and the keeper retainer on top of the keeper. Thread the 4-40 screws, washers and nuts into the body, but do not tighten. Next with a flashlight look though the hole in the keeper and locate the cathode tip. Move the keeper until the cathode tip and the hole in the keeper are lined up, and then tighten the 4-40 nuts to secure the keeper in place. Now affix the mounting bracket, using the two 10-32, 5/8 inch screws. Re-attach the hollow cathode assembly to the source with the acorn nut and tighten the new cathode gas line to the electrical isolator.

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 30 minutes. **Caution source may still remain too hot to touch.**

7.3.1 Modular Anode Assembly Remove the modular anode 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 (Fig. 7-9). Remove the three 1/4-20 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 (Fig. 7-10). Next remove the three 10-32 nuts, washers and 10-32M insulators illustrated in Fig. 7-10. The gas distributor assembly may now be removed exposing the additional four 10-32M insulators and gas reflector that need to be removed (Fig. 7-11). After removing the insulators and gas reflector, the remaining four 10-32M insulators and 10-32 sputter cups that rest on the anode support may now be removed (Fig. 7-12). This completes the disassembly of the modular anode assembly. Replace any of the eleven 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.

7.3.1.1.1 Water Break Replacement To replace the water breaks for the EH2000 first remove the modular anode 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 (Fig. 7-9). Remove the three 1/4-20 gold plated socket head cap screws from the gas distributor assembly and the front outer cylinder from the front plate (Fig. 7-9). Next remove the three 10-32 nuts, and washers and 10-32M insulators illustrated in Fig. 7-9. The gas distributor assembly may now be removed exposing the additional four 10-32M insulators, back inner cylinder and gas reflector that need to be removed (Fig. 7-10).

After removing the insulators, the back inner cylinder and gas reflector, the remaining four 10-32M insulators and 10-32 sputter cups that rest on the anode support may now be removed (Fig. 7-11). Remove the gold plated 6-32 nuts that hold the anode support to the anode. Remove the anode support plate, slide the fiberglass break sleeves off the water breaks and place the anode facing down on the work surface (Fig. 7-12). Loosen the ¼ inch Swaglok™ nuts and remove the water breaks (Fig. 7-12) This completes the disassembly of the modular anode assembly. Replace any of the eleven 10-32M insulators and or two water breaks if they appear to be damaged or coated. Contact KRI for any replacement parts.

7.3.1.2 Anode Connector The anode connector is shown in figure 7-13. 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. Though 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. Pyrolytic graphite should be used for inert gases, and stainless steel should be used for reactive gases. 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.

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 cable on the outer shell.

7.3.4 Alternate Parts List Table 7-1 is a list of alternate 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 Alternate Parts List

Description	Part number
Magnet, inert gas version, 51 mm (2 in.) length	MS09-01
Reflector, pyrolytic graphite, inert gas	EH10-12-C
Magnet, reactive gas version, 45 mm (1.75 in.) length	MS09-01L
Anode, 23 mm (0.9 in.) I.D.	EH10-141WC
Reflector, stainless steel, reactive gas	EH10-12-S
Reflector, tantalum	EH10-12-TA*
Reflector, titanium	EH10-12-TI*

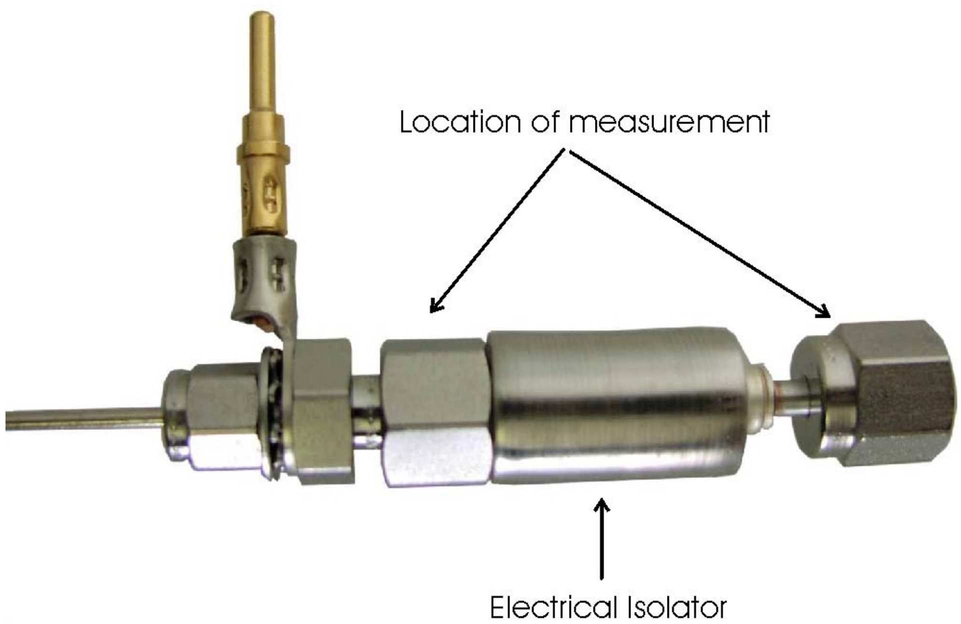


Fig. 7-1 Hollow cathode electrical isolator.

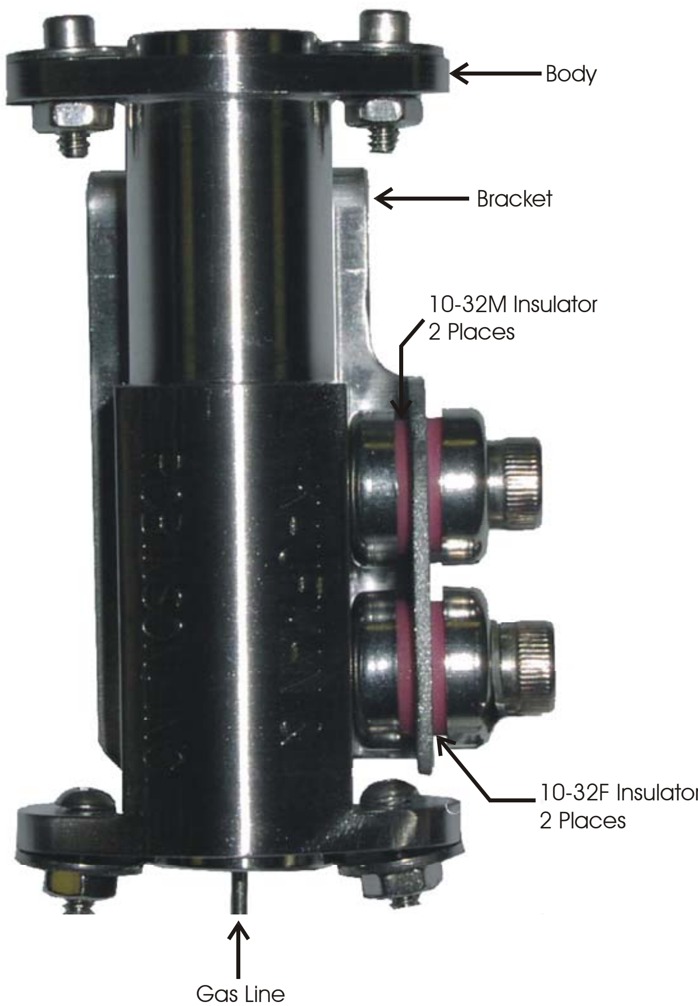


Fig. 7-2 Body, bracket, gas line and insulator.

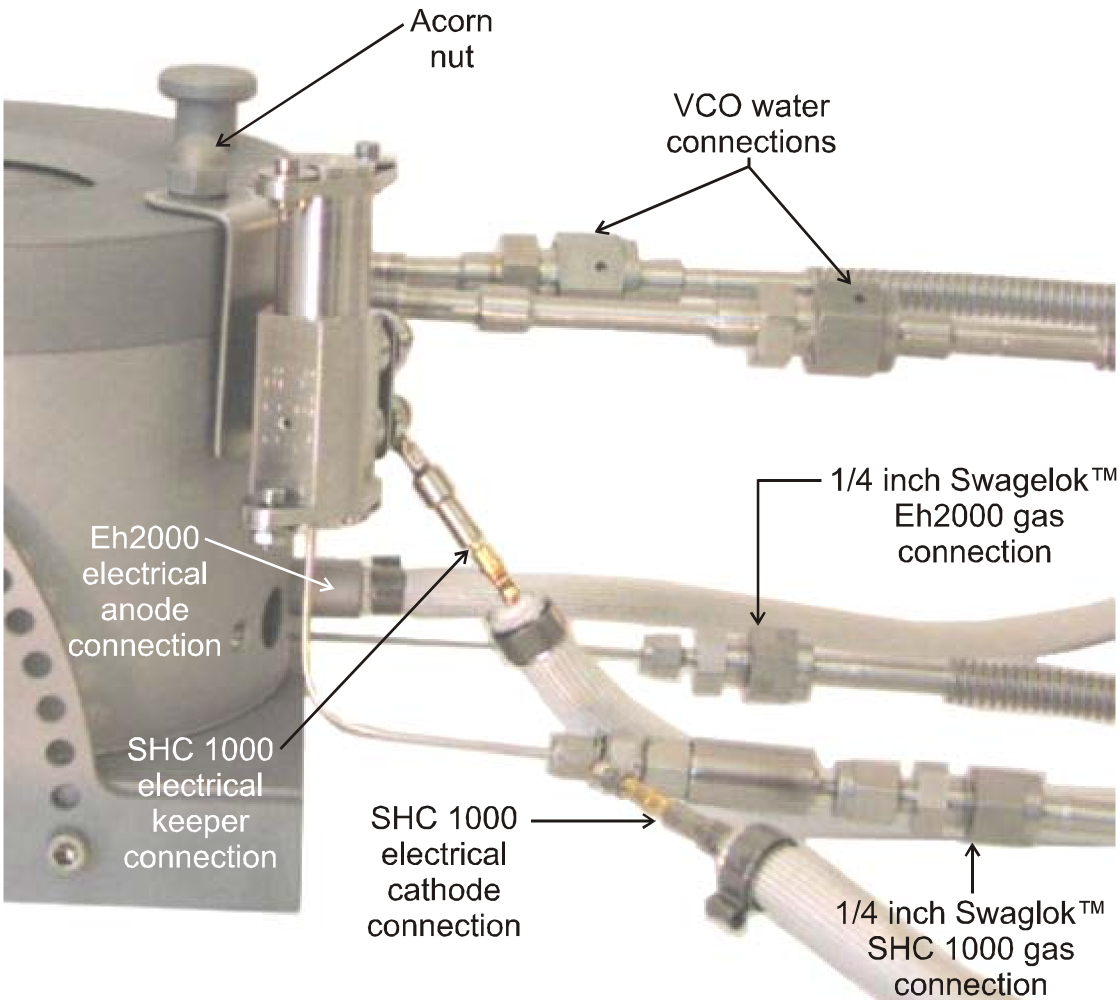


Fig. 7-3 EH2000 and SHC1000 connections.

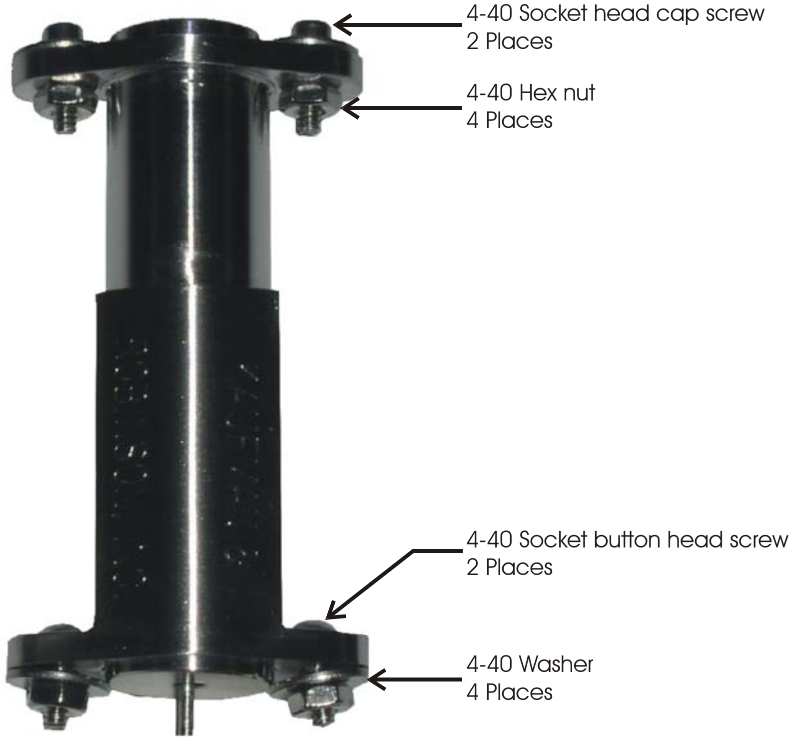


Fig. 7-4 4-40 Screws, washers and hex nuts.

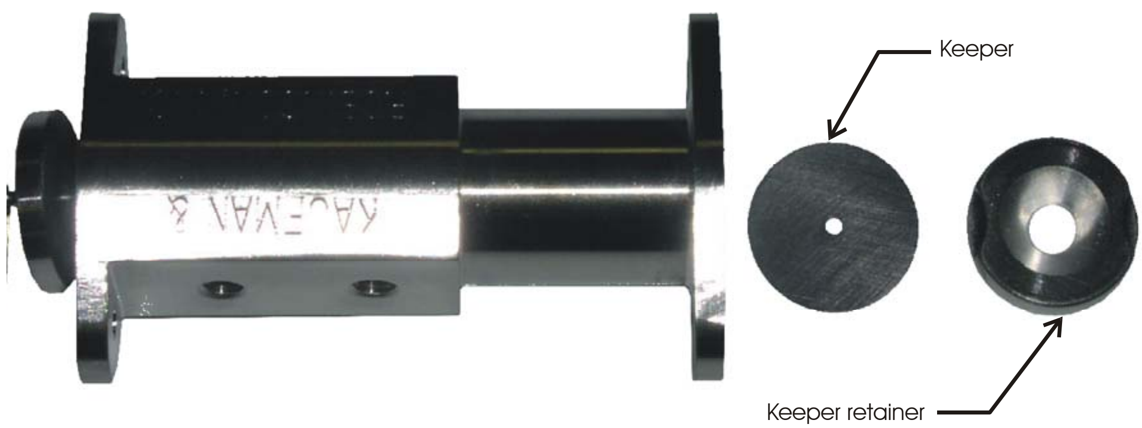


Fig. 7-5 Keeper and keeper retainer removed.

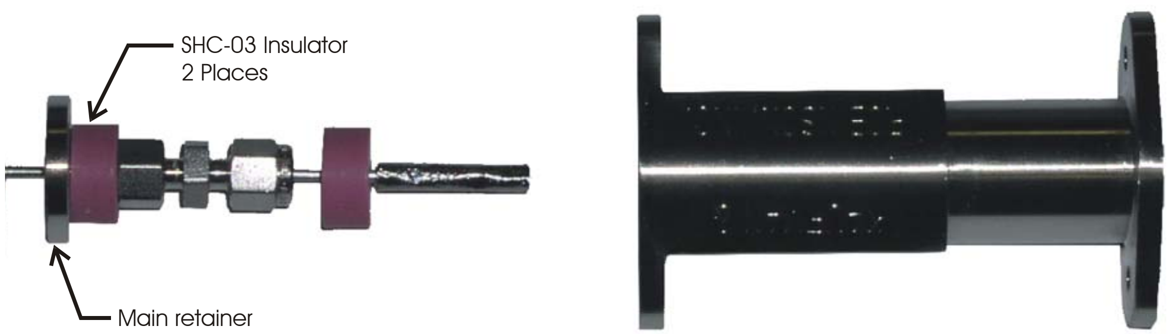


Fig. 7-6 Main retainer and SHC-03 insulators.

Fig. 7-7 Swagelok™ nut and SCH-03 insulator.

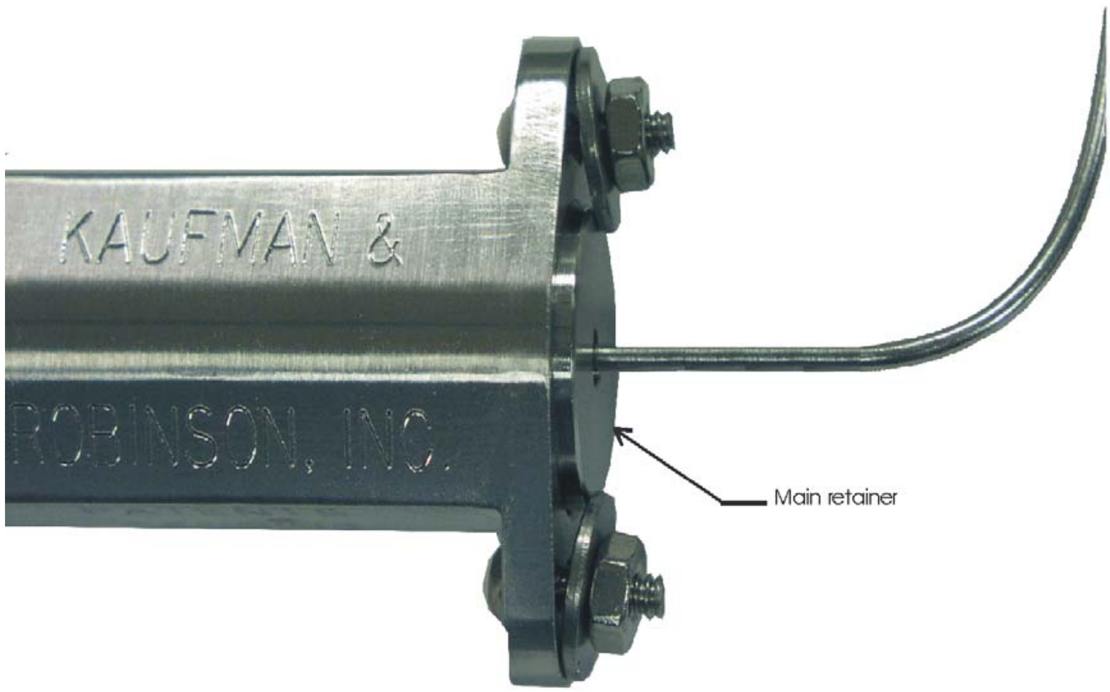


Fig. 7-8 Main retainer.

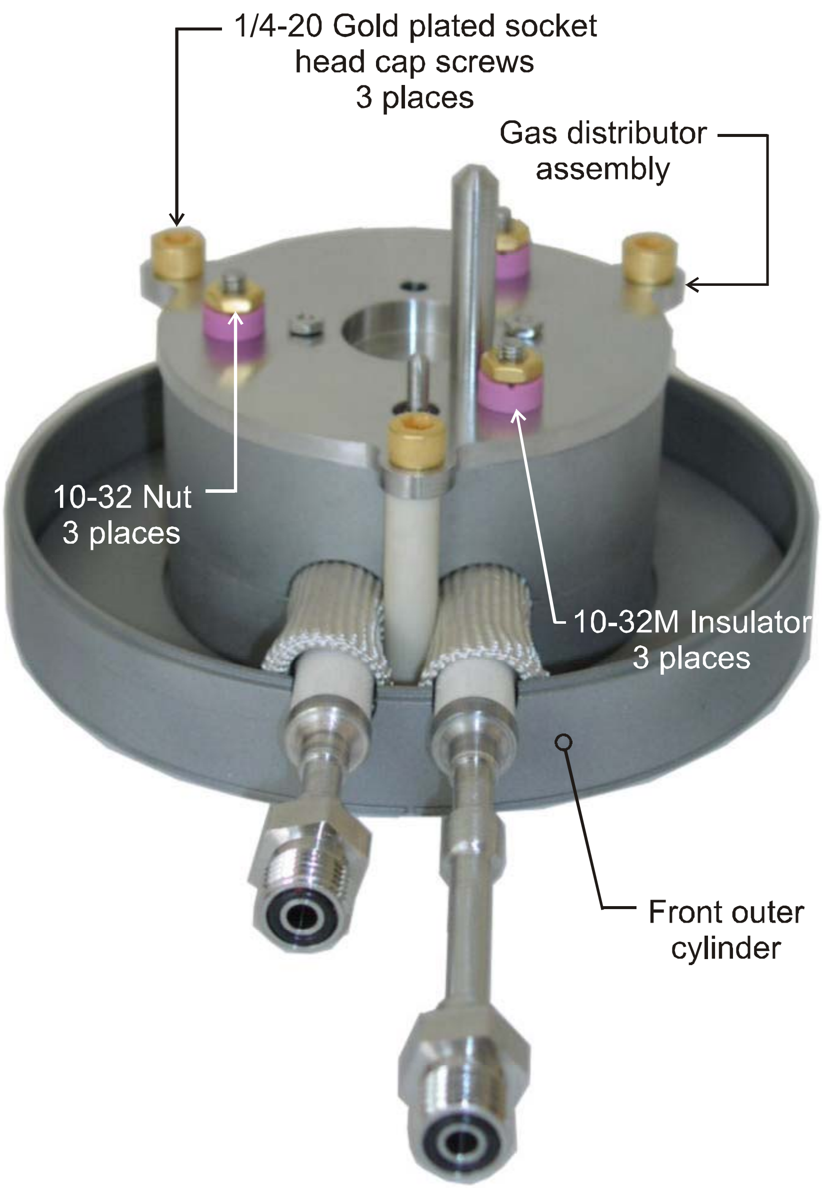


Fig. 7-9 Modular anode assembly.

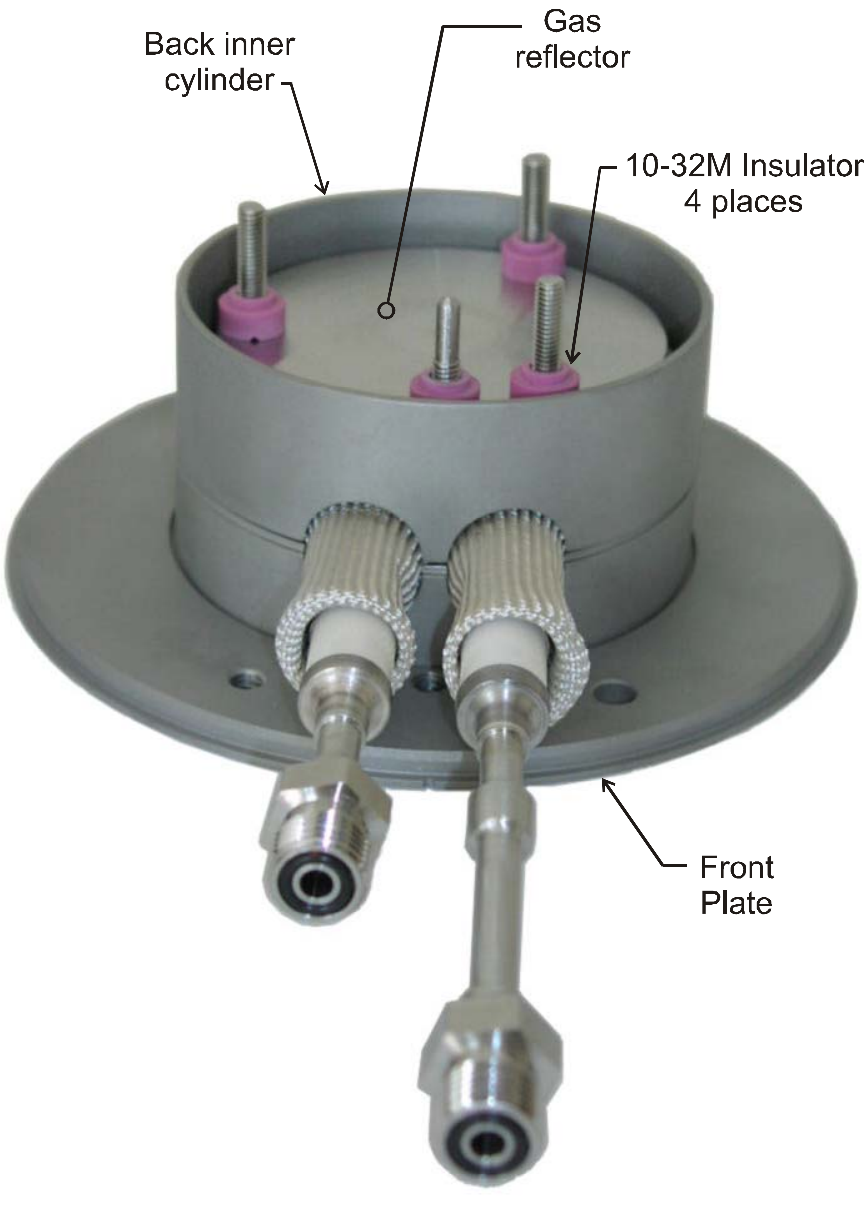


Fig. 7-10 Gas distributor assembly.

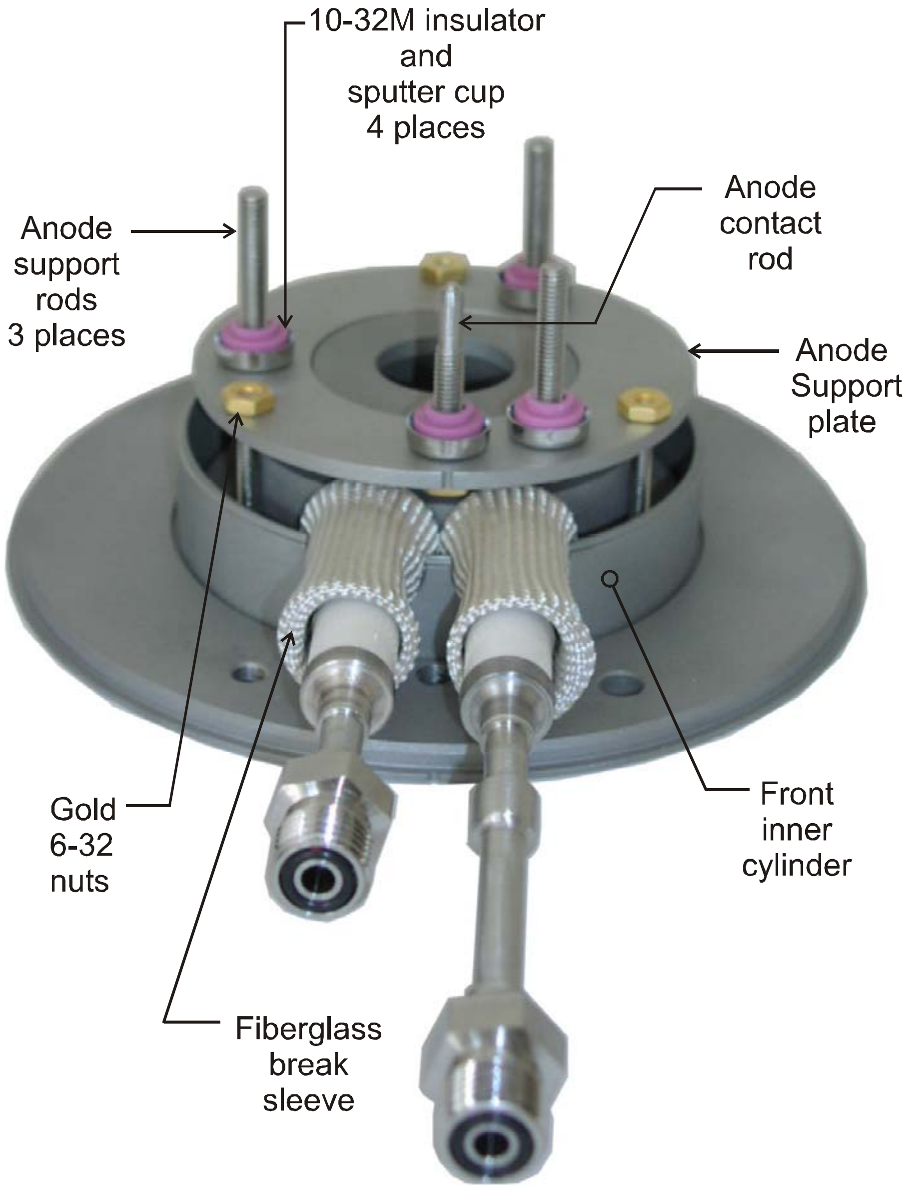


Fig. 7-11 Gas reflector and 10-32M insulators.

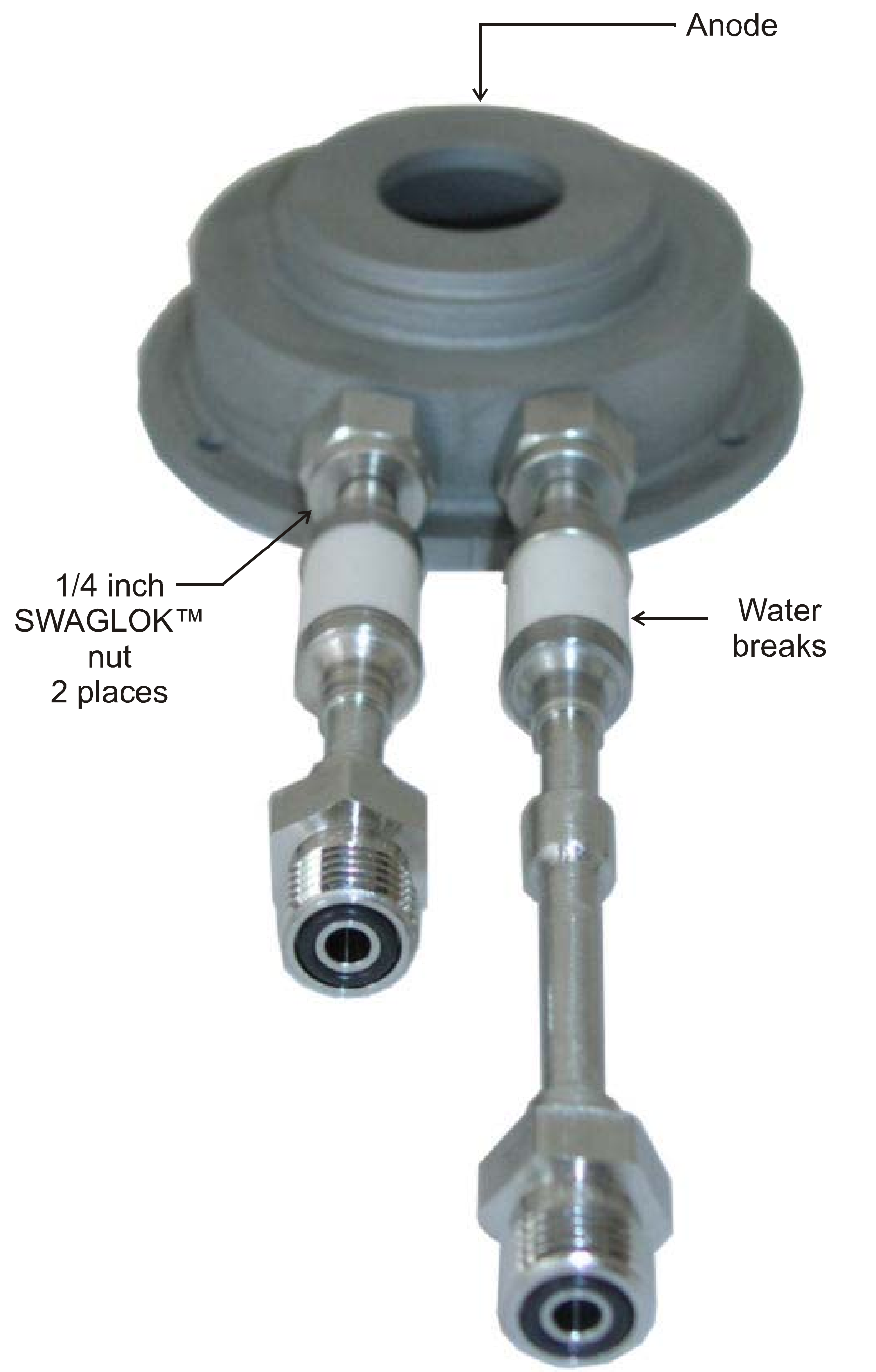


Fig. 7-12 Anode support, 10-32M insulators and 10-32 sputter cups.

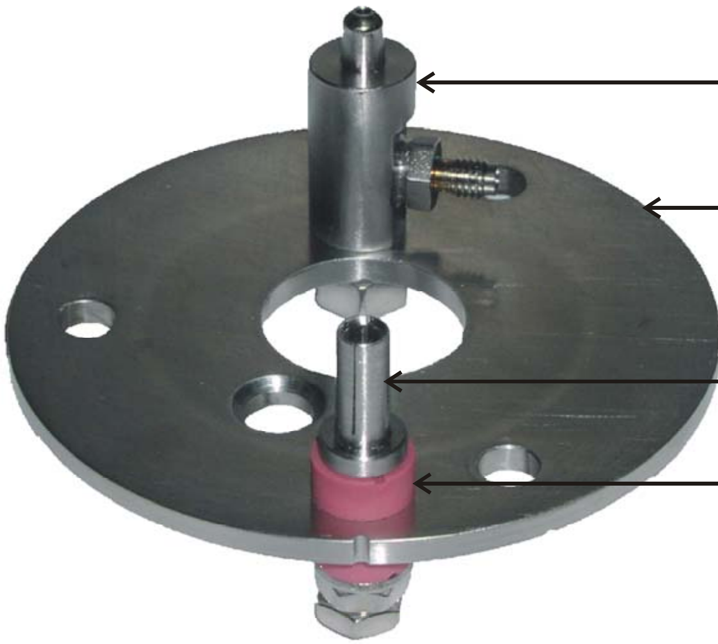


Fig. 7-13 Anode connector, 10-32M insulators and inner ring.

8 DIAGNOSTICS

8.1 General

The following information is intended to facilitate troubleshooting and repair of the EH2000 ion source and the hollow cathode electron 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 connections are in good condition and that the gas circuit is complete from the gas bottle to the ion source. A quality water source with correct flow, see section 2.4.3, is also assumed.

NOTE: PRIOR TO OHMMETER CHECKS ALL POWER TO SUPPLIES MUST BE SHUT OFF AND DISCONNECTED.

8.2 HCES

If there are difficulties in starting the HCES or in the operation, tests can be conducted immediately with an ohmmeter at the electrical feedthrough to assist in diagnostics prior to venting the vacuum system to atmosphere. These ohmmeter tests would be to determine if there is less than infinite resistance between the cathode and the keeper (body of the cathode), and between the cathode and keeper to the grounded vacuum facility. Any resistance indicated less than maximum should be cause for maintenance on the HCES or the vacuum cables that connect to the HCES.

If the fault in operation is due to an open in the electrical circuit, the vacuum system may need to be vented to atmosphere to find the open circuit. Continuity checks can be made from the atmosphere side of the electrical feedthrough to the HCES body and cathode. If the resistance indicated on the ohmmeter is maximum an open circuit is evident.

Refer to the Diagnostics section 8 for assisting in failure analysis. Refer to the Maintenance section 7 for corrective action of failure.

8.3 EH2000

In the event that abnormalities occur in the staring or operation of the EH2000 source, an ohmmeter check of the EH2000 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 EH2000 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.

8.4 Diagnostic Table

The following table may be used to assist in determining faults and corrective action for the HCES and the EH2000.

Table 8-1. Diagnostic Table

Symptom	Possible Cause	Correction
Inability to start HCES	Gas flow too low or leakage in gas line	Increase gas flow or tighten fittings
	Failure of the HCES tip	Replace HCES tip and associated hardware
	Insulating coating on the cathode body and/or keeper	Perform maintenance on cathode, cleaning the keeper and body
	Keeper hole enlarged	Replace keeper
	Contaminated gas supply	Refer to Inspection and Installation section 2.4.3
Inability to achieve required bias current	Alignment of the cathode tip to the keeper is not correct	Align cathode tip to the keeper
High bias current, low bias voltage	Cathode shorted to ground	Inspect gas isolator, replace if necessary
		Inspect insulators located within the HCES body for coatings or damage.
	HCES body shorted to ground	Inspect insulators that isolate the cathode support from the ion source, replace coated or broken insulators

Symptom	Possible Cause	Correction
		Inspect electrical cable and feedthrough for possible damage
Keeper voltage maximum, no keeper current	Open connection in the electrical circuit	Perform continuity tests with a ohmmeter to locate open
Bias voltage normal, no bias current	HCES not started Open in electrical circuit	Verify keeper voltage and current are normal Verify gas flow setting into the HCES Perform continuity tests with a ohmmeter to locate open
Lifetime of HCES is short	Contamination of the HCES Use of reactive gases within the vacuum environment	Refer to Inspection and Installation section 2.4.3 Increase gas flow to the HCES
Discharge voltage present, no discharge current	Broken or incomplete connection in the electrical circuit	Review electrical connections from the power supply, through cabling and feedthrough, to the ion source
Discharge current high, discharge voltage very low	Discharge (anode) short to ground	Inspect electrical cables and feedthrough for damage Insulators that isolate the anode and anode contact within the ion source need replacement

Symptom	Possible Cause	Correction
Excessive reflector erosion	Reflector short Incorrect reflector installed for the gas in use	Replace coated insulators or remove any debris Install the correct reflector
Life time of water breaks Is short	High resistivity in cooling water	Use distilled water
Inability to start a discharge (Ion source)	HCES not started Low gas flow Poor electrical connections Insulating layer on anode	Start the HCES Increase gas flow Calibrate flow controller Check all electrical connections to insure electrical circuit is complete and the electrical connections are reliable. Clean the ion source anode

9 WARRANT Y

All equipment supplied by KRI, Kaufman & Robinson, Inc., for use with the EH2000-HC and Controller are warranted for one year against manufacturer defects in materials or workmanship. The warranty on the equipment is for one year, effective the date of the original shipment, provided that the equipment has been operated and maintained according to the operating procedures outlined. KRI will service and at its option repair or replace defective parts, free of charge during the one-year warranty period, at the KRI facility. This warranty excludes defects resulting from misuse or unauthorized modification. This warranty does not cover expendable parts; expendable parts are as follows:

Alumina Insulators
Hollow Cathode Tip
Hollow Cathode Keeper
EH2000 Reflector
Gas Line Isolator
Vacuum Cables
Water Breaks
Fiberglass Break Sleeve

This warranty supersedes all other warranties expressed or implied. KRI assumes no liability for damages or loss of production. Report defects or problems to KRI immediately. For return of equipment for repair contact KRI to arrange for a return materials authorization (RMA) number prior to shipment of the equipment to KRI facilities.

For Service or Repair, contact KRI:

Kaufman & Robinson, Inc.
1306 Blue Spruce Dr. Unit A
Fort Collins, CO 80526
(970) 495-0183
(970) 484-9350 (FAX)

Please indicate the following items relating to the defect with the item to be returned:

Product
Serial Number
Detailed description of problem
Date of purchase
Name of Company with address, and contact person

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