eH1000 FILAMENT ION SOURCE MANUAL

Kaufman & Robinson, Inc.
1330 Blue Spruce Drive
Fort Collins, Colorado 80524
Tel: (970) 495-0187
www.ionsources.com

January 2020, Version D
Part Number: 9007-EH-1001

This Page is Intentionally Blank

Contents

Tables

Figures

LEGEND OF SYMBOLS

⚡ **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.

This Page is Intentionally Blank

2. INSPECTION AND INSTALLATION

This chapter describes how to install the Kaufman & Robinson, Inc. (KRI®) eH1000F 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 physical 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 Warranty, Section 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

2.2.1 eH1000 Ion Source

The eH1000F 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 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, 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. Vacuum cables from the electrical feedthrough connect to the ion source at the outer shell 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. 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 Electrical Feedthrough Assembly

The electrical feedthrough assembly is approximately 24.62 cm (9.69 in.) in length and 5.08 cm (2 in.) in diameter without cabling attached. The overall length of the feedthrough with the vacuum and atmosphere cables is 32.39 cm (12.75 in.) These dimensions are shown in Figure 2-2. The overall length of the feedthrough assembly can vary slightly depending on the thickness of the material that the feedthrough is attached to.

2.2.1.5 Gas Feedthrough

The gas feedthrough is fabricated of stainless steel and is designed to fit into a 2.54 cm (1 in.) diameter port. The overall length of the feedthrough with gas lines attached is approximately 29.9 cm (11.77 in.) as shown in Figure 2-3.

2.2.1.6 Cathode Filament

The cathode filament is fabricated using 0.05 cm (0.020 in.) tungsten wire and is fabricated with 15 turns of wire. The cathode filament is attached to the ion source using two cathode supports that facilitate ease of removal from the ion source for replacement.

2.2.1.7 Optional Water Cooling

The eH1000 has an optional, water-cooled, front and back plates. The following details the plates and the feedthrough.

2.2.1.7.1 Water-Cooled Front Plate

Typically, the connections for the water-cooled front plate for the eH1000 line up with gas line for the source and have ¼” male VCO fittings. However, there are multiple options for the angle of entry for the water hose connections, as well as the connections themselves. See Figure 2-7.

2.2.1.7.2 Water-Cooled Back Plate

The water-cooled back plate comes with ¼” male VCO fittings that are alligned 90° from the gas line. The water conections also angle upward 30° so that the source can still be mounted to an optional transport if neccessary. See Figure 2-7.

2.2.1.7.3 Water Feedthroughs

The overall dimensions of the water feedthrough depends on the type of feedthrough. Typically, a one inch bolt feedthrough or a 2¾” CF flange feedthrough are used. The vaccuum side has ¼” male VCO fittings, while the atmosphere side fo the feedthrough has See Figure 2-8.

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 XXXXFRSXXX indicates that the ion source is an eH1000F ion source, hot filament version, configured for reactive gas using a stainless steel reflector. The first four numbers indicate the year and month that the source was manufactured. 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 indicate 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. 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 Chapter 7 for part numbers and descriptions.

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

Table 2-1. Inventory List

Quantity	Description
1	eH1000F ion source
1	Vacuum discharge cable
2	Vacuum filament cable
4	Large cathode support
1	Cathode jig
1	Electrical feedtrhough assembly
1	Feedthrough, gas, hot filament
1	Spare reflector, pyrolytic graphite

Quantity	Description
1	Spare reflector, stainless steel
1	Spare parts kit

2.4 Installation

⚠ **CAUTION:**
Use clean lint free gloves to handle any of the components to prevent contamination.

The eH1000F 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 when installing the ion source. 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 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 Figures 2-1 through 2-9. Standard installation procedures used in the vacuum industry should be adhered to when installing vacuum fittings and feedthroughs. All components have been cleaned prior to shipment. Use clean lintfree 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, Figure 2-4. 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 cor-responding holes in the ion source and the dimensions are shown in Figure 2-4. 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 2-5. 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 Filament Cathode

The filament cathode can be installed onto the ion source at any point during the installation procedure. Four cathode supports have been provided with the ion source. When the cathode on the ion source breaks a new cathode, and supports, are ready to be installed for continued operation of the ion source. When installing a new cathode onto the cathode supports the cathode can be attached to each support. While holding the cathode supports, slightly stretch the cathode outwards as the supports are inserted into the ion source or onto the cathode jig. Figure 2-6 shows a cathode and cathode supports installed onto the cathode jig. Two of these supports are used during operation of the ion source while the remaining two are spares. A cathode jig has been provided so that the two spare supports can be installed onto the jig with a new cathode.

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 can contaminate the ion source. Gas connections can be made with reference to Figure 2-7.

The eH1000F source can be operated on different gases. These gases must be 99.999% pure.

Gas connections are made to the eH1000F 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 bottle, 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. Information regarding the use of the Gas Controller can be found in the eH1000F Ion Source Filament Cathode Version Controller Manual. **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 feedthrough 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 vhamber 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 circuit is now ready for normal operation.

2.4.4 Electrical Connections in the Vacuum Chamber

2.4.4.1 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. The anode connection is made in the center clearance hole as shown in Figure 2-9. 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 pin located within the ion source. The opposite end of the discharge cable connects to the vacuum feedthrough, see Electrical Feedthrough Connections, Vacuum Side.

2.4.4.2 Filament Cathode

Electrical connection to the filament cathode is made using two cables. These cables are fabricated primarily 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.

2.4.4.2.1 Cathode Connection

Connection to the cathode is made using two cables. These cables connect to the ion source at the outer cylinder, near the back plate. These cables connect on both sides of the center clearance hole, as shown in Figure 2-7. The other end of these cables connects to the electrical feedthrough assembly, see Electrical Feedthrough Connectionsat Vacuum, Section 2.4.5.1, below.

2.4.5 Electrical Feedthrough

Install the electrical feedthrough as shown in Figure 2-9. To do so, loosen the four set screws on the safety enclosure, see Figure 2-9. 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 cathode wires from the feedthrough by loosening the screws on the inline connectors. Install the feedthrough in a 1 in. port of the vacuum chamber. Then reinstall the wires and connector to the feedthrough. Refer to Figure 2-8b for proper locations, and then reinstall the safety enclosure.

2.4.5.1 Electrical Feedthrough Connections at Vacuum

Connections from the ion source are made to the electrical feedthrough as follows with the use of Figure 2-8. 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 and discharge (anode) cables through the appropriate holes of the feedthrough sputter cover. 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.

Note: Either cathode connection on the feedthrough can connect to either cathode connection on the main module of the ion source.

2.4.5.2 Electrical Connecions at Atmosphere

A cable has been provided for connection from the controllers to the electrical connector attached to the safety enclosure. The cable end uses a locking mechanism to secure the connectors. For electrical connections at the power supplies refer to the power supply manual.

Figure 2-1. The eH1000F ion source with the anode module removed.

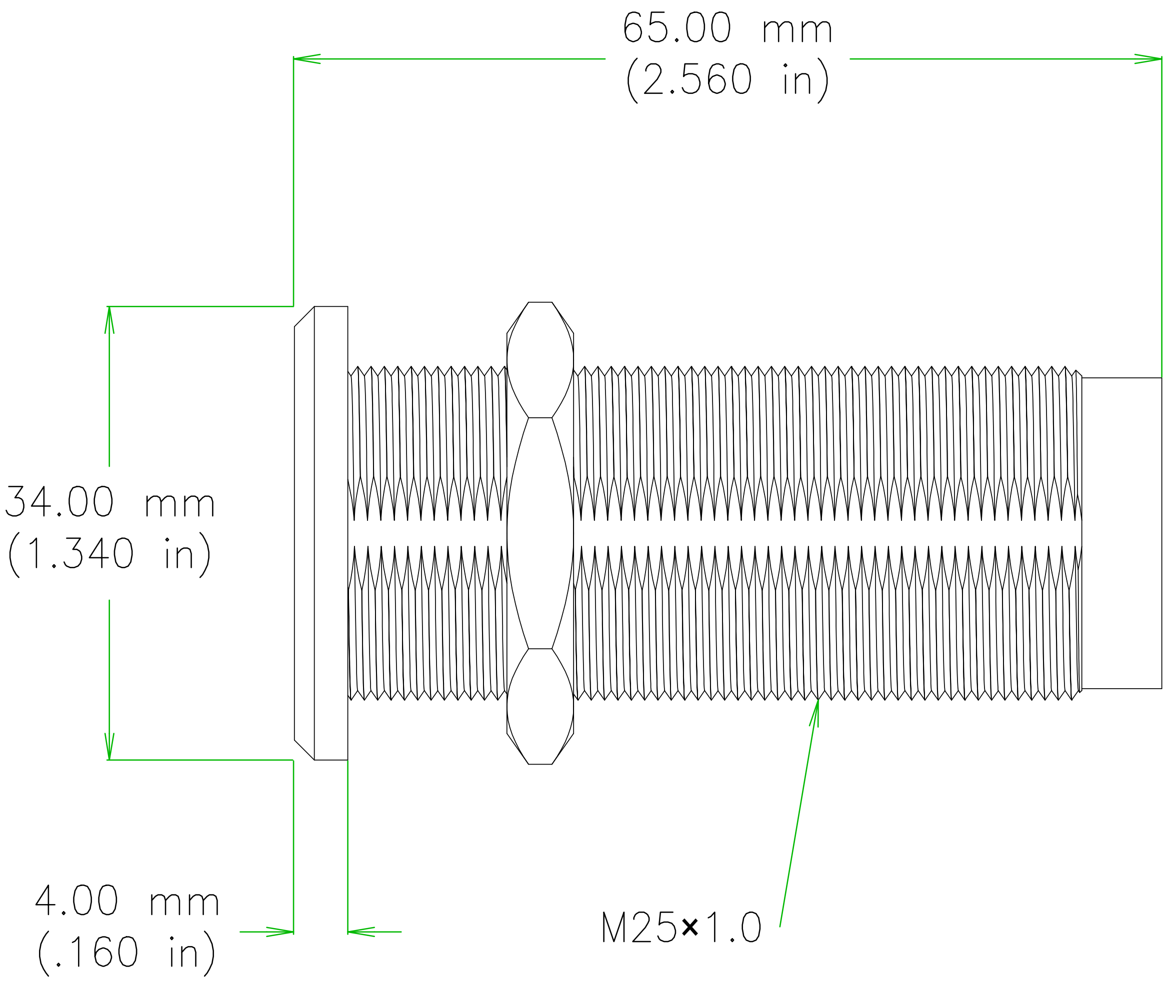

Figure 2-2. 1 inch diameter bolt-hole LEMO feedthrough dimensions.

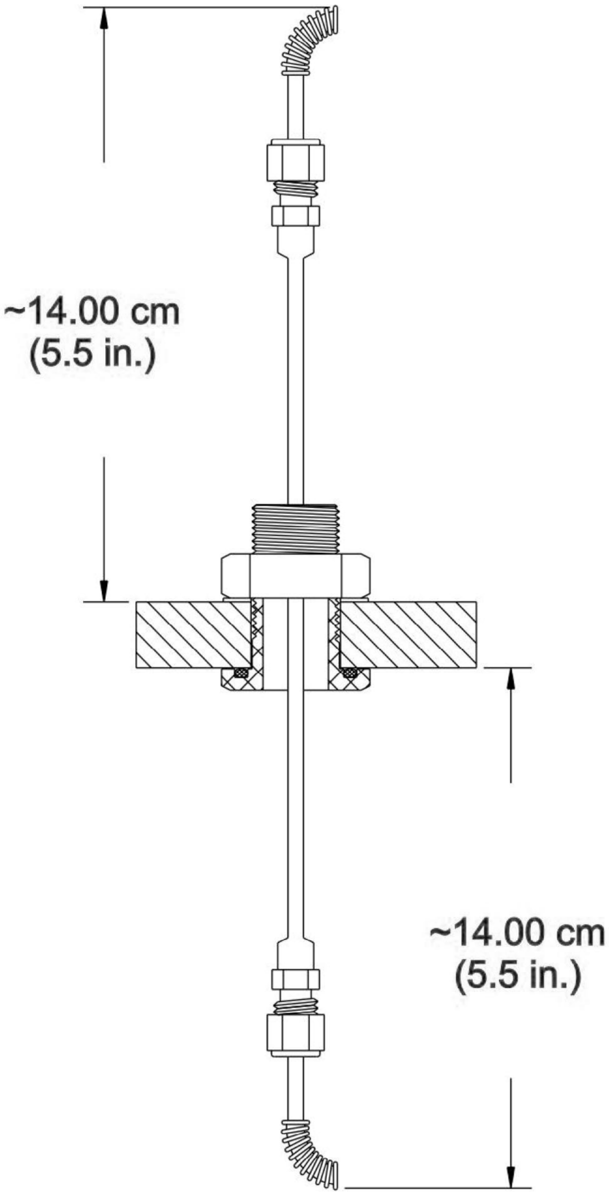

Figure 2-3. Gas feedthrough dimensions

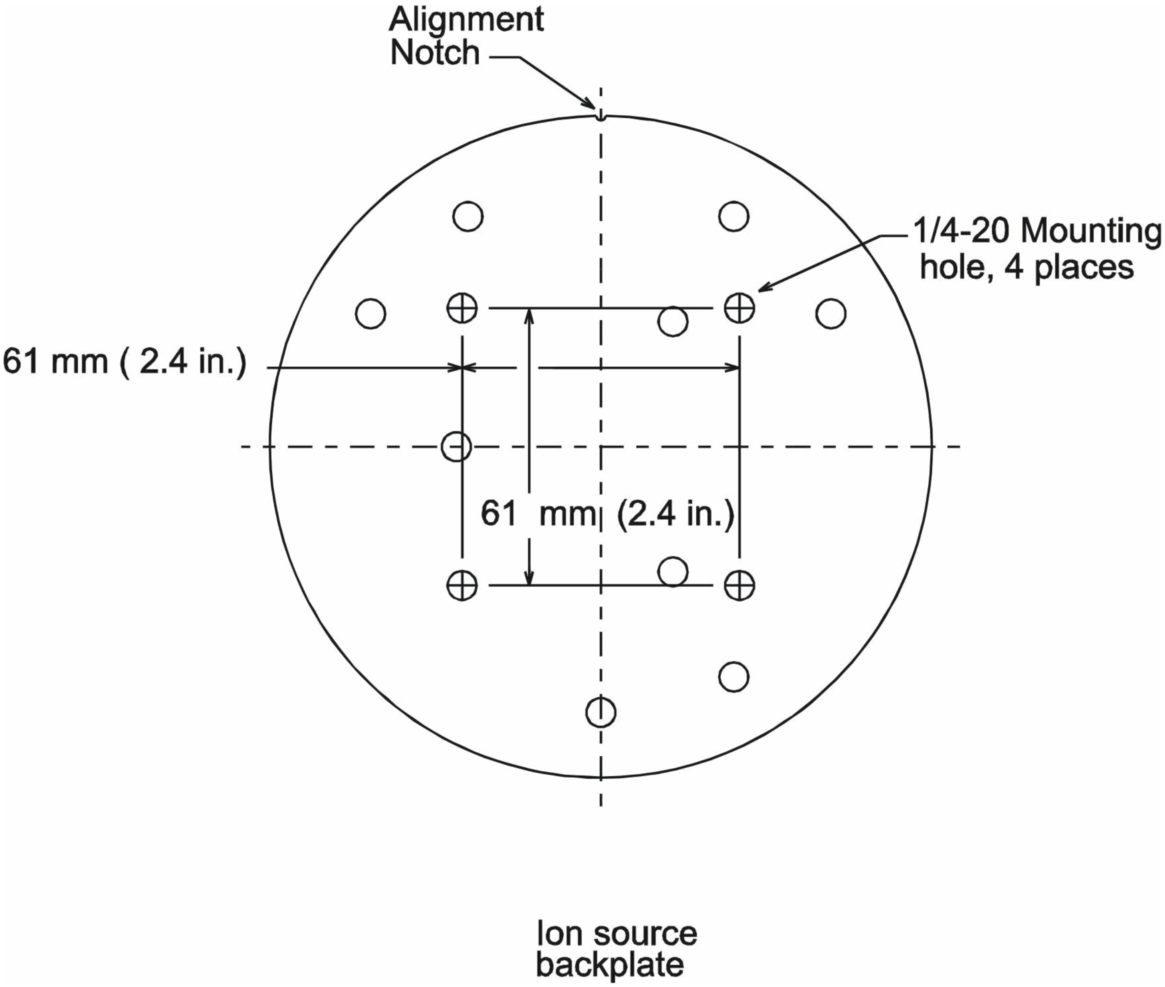

Figure 2-4. Mounting hole locations for the eH1000F ion source

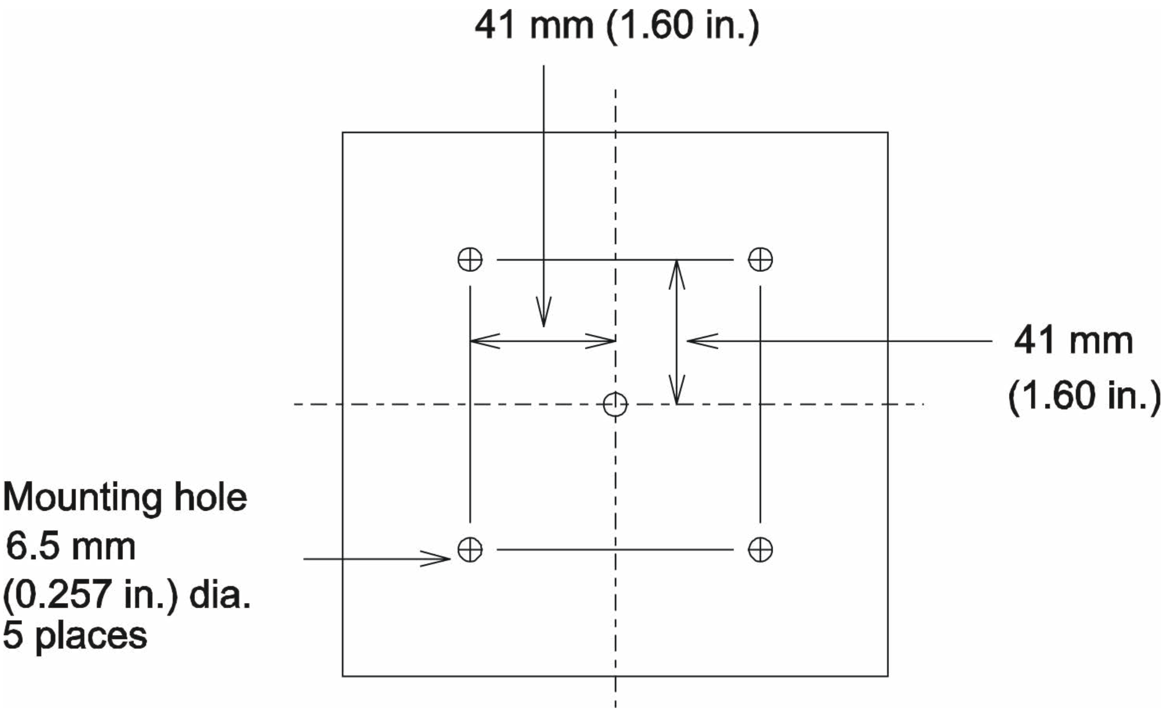

Figure 2-5. Mounting hole locations for the (optional) transit support

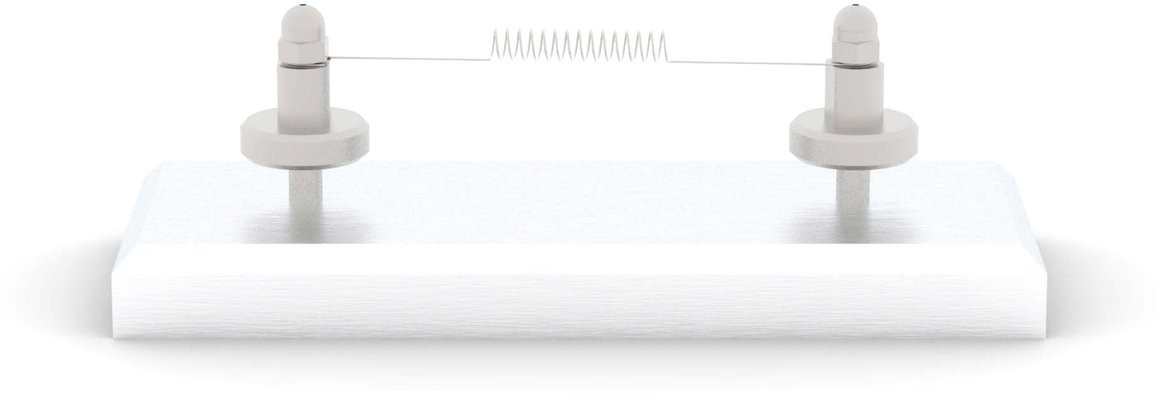

Figure 2-6. Filament cathode installed in the cathode jig

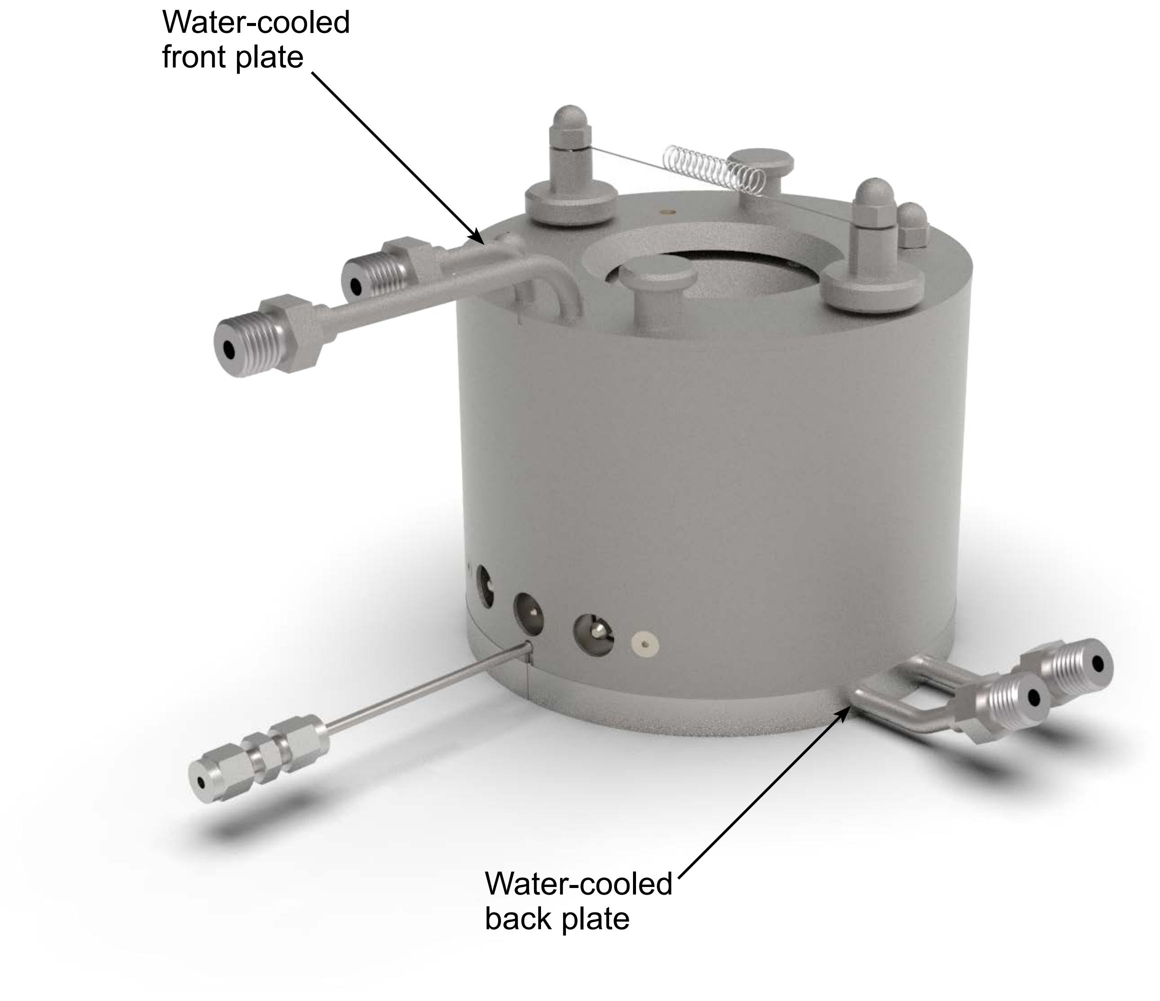

Figure 2-7. Typical configuration of water-cooled front and back plates for eH1000.

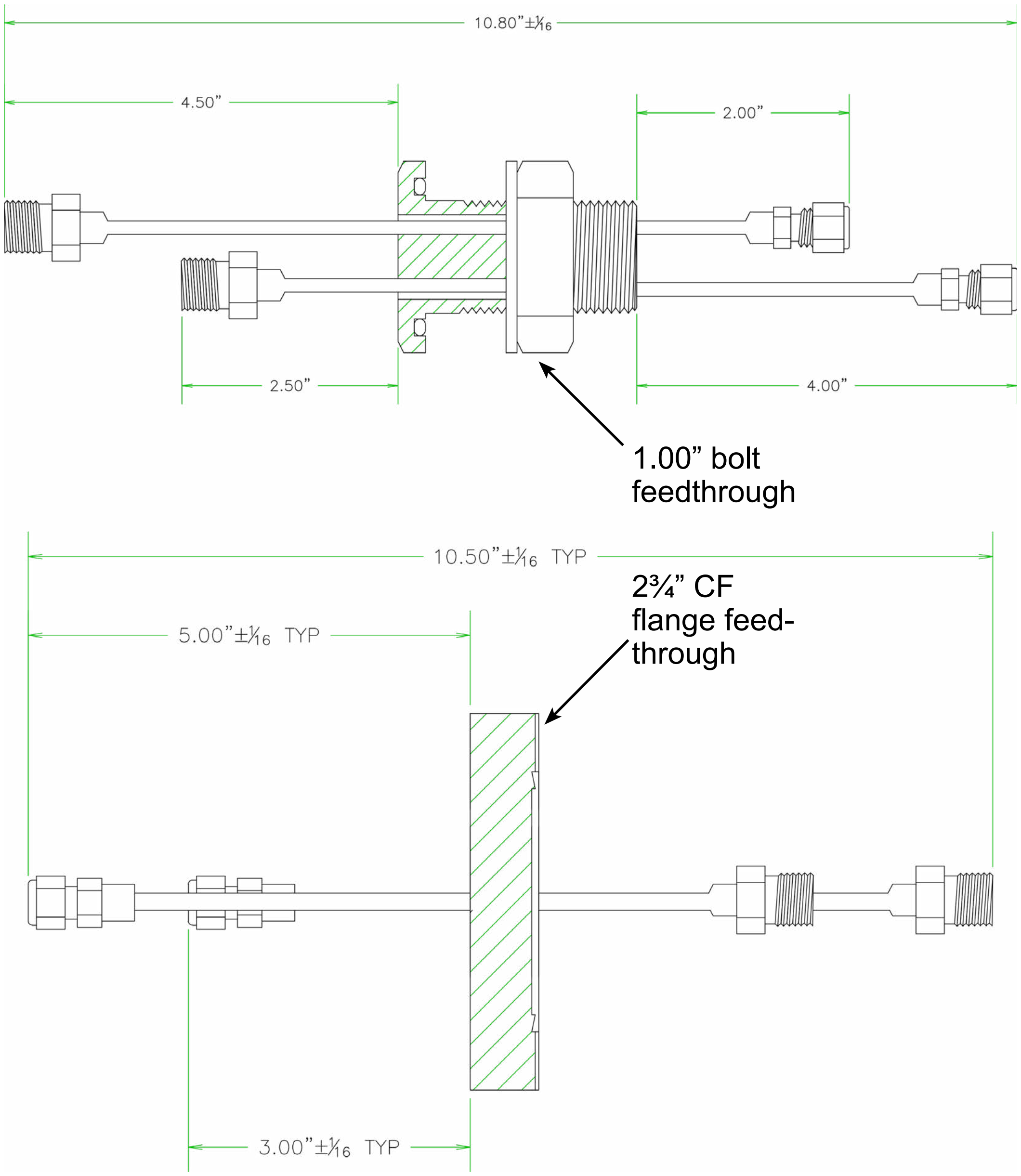

Figure 2-8. Dimensions for typical water feedthroughs.

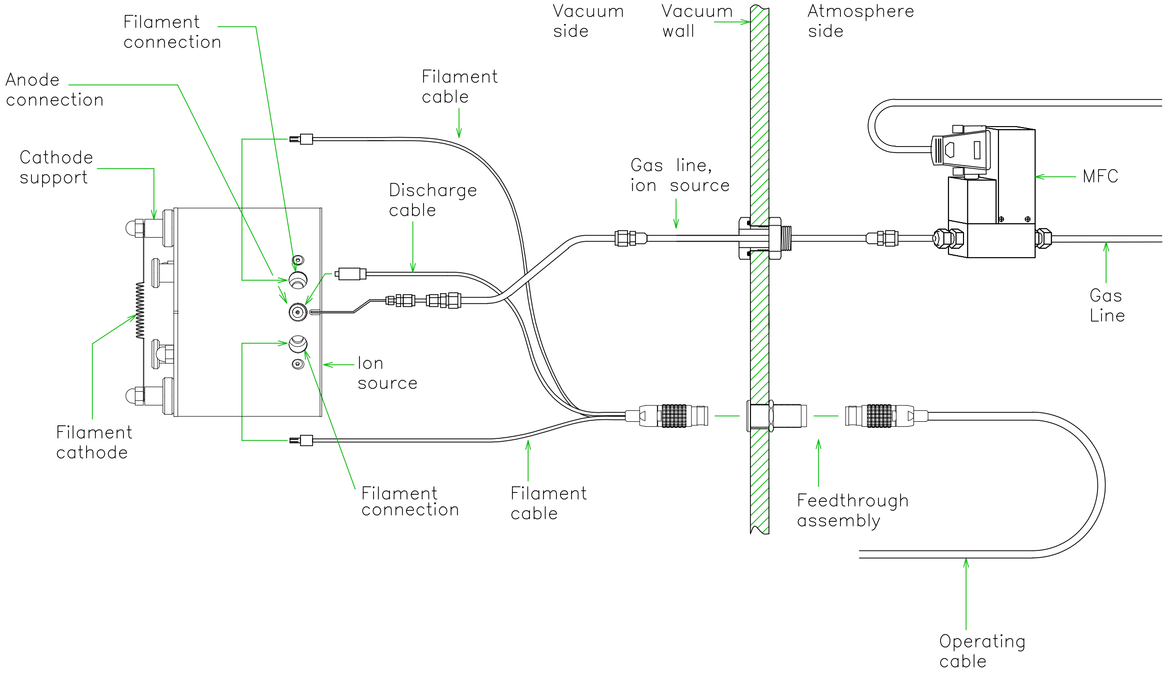

Figure 2-9. Installation drawing for the eH1000F ion source

This Page is Intentionally Blank

3. APPLICATION CONSIDERATIONS

Operation of the eH1000F ion source can be accomplished with the use of the following information. Operating parameters for the ion source can be found in Section 6 of this manual. Additional information can be found in this section to assist with operation of the ion source. Prior to operating the eH1000F ion source, review all of the details outlined in the Section 2 of this manual and the Installation section for the eH1000F 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 Operation procedures outlined in the eH1000F Controller manual and is familiar with controller operation.

3.1 Coverage Calculations

In general, cleaning and ion assist applications require some minimum dose or rate. However, 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 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 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 improve or enhance 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 eH1000F ion source. More detailed information on the controller is presented in the manual for the controller.

4.1 Scematic Diagram

Operation of the eH1000F 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 argon introduced into the ion source.

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

A 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 magnet. The electrons created by the emission bombard the neutral ions or 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 anode potential is established within the plasma due to the interaction of electrons with the magnetic field, and the applied anode potential.

This description is summarized. For more information, refer to the literature in the reference 10.

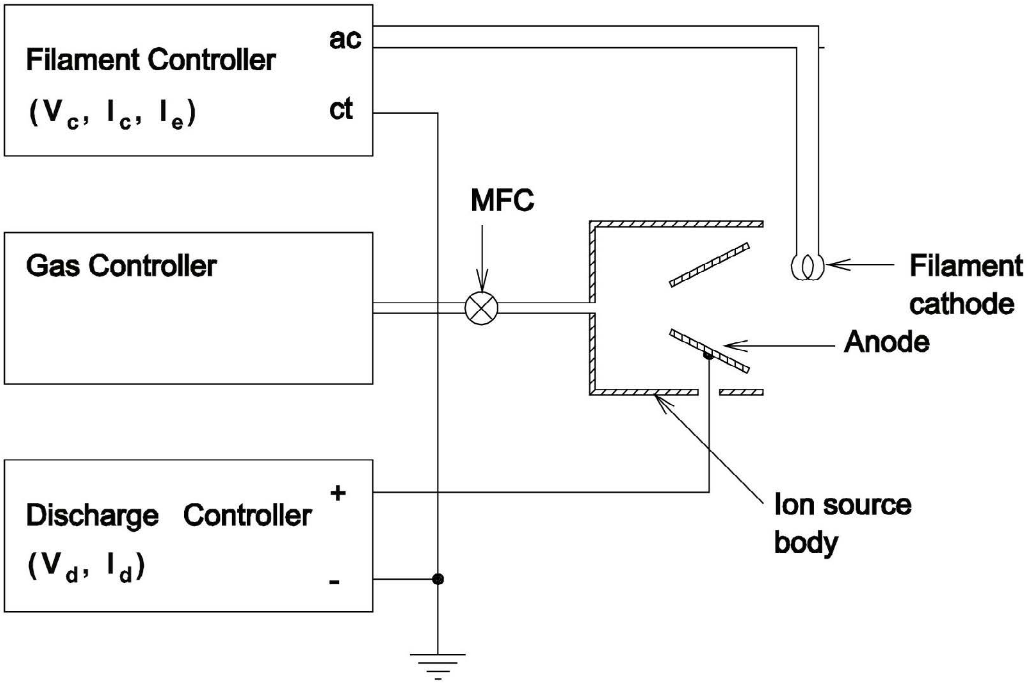

Figure 4-1. Schematic diagram of the eH1000F ion source

5. OPERATION

Operation of the eH1000F 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 eH1000F ion source, review all of the details outlined in the Chapter 2 of this manual and the Installation section for the eH1000F 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 Operation procedures outlined in the eH1000F controller manual and is familiar with controller operation.

5.1 Cathode Filament

- Turn on the power to the Filament Controller.

- Adjust the cathode emission until the cathode current meter reads 14-18 amps.

5.2 Starting the eH1000F Ion Source

- Adjust the gas flow into the ion source to a flow of 15-20 sccm.

- Adjust the voltage control on the Discharge Controller to maximum.

- Adjust the current control on the Discharge Controller 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.

- Adjustments to the cathode emission will be required while increasing the discharge current in order to keep the cathode emission slightly greater than or equal to the ion source discharge current.

- Adjust the discharge voltage to 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 ion source is operating, slight adjustments may be needed to achieve the desired operating conditions.

6. CHARACTERISTICS

This chapter includes typical performance characteristics for a KRI® eH1000F ion source. The data provided should be used as a guide for operating parameters of the ion source.

6.1 Cathode Filament

The cathode filament can operate up to 12.5 amps of emission current. The filament lifetime lasts anywhere from 1 hour to 24 hours and are shown in Figure 6-1 and Figure 6-2. The lifetime depends on the discharge voltage and discharge current used. Generally speaking, the higher the discharge voltage and current used, the shorter the lifetime of the cathode filament.

There are a few other factors that influence cathode lifetime. Vacuum chamber pressure, impurities present, type of gas used and the operating conditions also affect cathode lifetime. Operating a filament cathode at pressures in the 10^{-4} Torr range will have increased lifetimes as compared to operation in the 10^{-5} Torr range.

6.2 Discharge Voltage

The eH1000F can operate at a range of discharge voltages from 40 to 300 volts with up to 8A of discharge current, and a maximum power limit of 850 watts of discharge power. The ion source must not be operated above 850 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	1.8
300	2.8
250	3.4
200	4.3
150	5.7
100	8.5

Figure 6-3 illustrates the range of operation for the ion source, at four different pump speeds using argon gas. The two foremost curves illustrate a reduced op-erating 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 3, 5 and 7 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 800 l/s (pink) illustrates the required gas flow for a given discharge voltage of 75 V and a discharge current of 3 A is approximately 19 sccm of argon. At a high pump speed of 1600 l/s, the curve (green) shows that the ion source will now require about 24 sccm of argon to obtain the same 75 V and 3 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 6-4 and 6-5 show the range of operation of the ion source using Oxygen and Nitrogen at a pump speed of 1600 l/s. 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.

In order to compare the vacuum pump speed of the users vacuum facility to the pump speeds shown in figures 6-3 through 6-5 the user should set the gas flow to 50 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 eH1000F ion source is shown in Figures 6-6 and 6-7. 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 Figure 6-6 against discharge voltage for various discharge currents. 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 requires high gas flows and for small decreases in the discharge voltage, a large increase in gas flow is necessary.

Figure 6-7 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 lower ion energy.

6.5 Ion Beam Profiles

Figure 6-8 is a sample retarding potential probe analysis curve on axis of the ion source. The mean energy shown in Figure 6-7 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.). Figure 6-9 illustrates both target configurations. Argon profiles can be found in Figures 6-10 and 6-11. Oxygen and Nitrogen profiles are included in Figures 6-12 through 6-15. The ion current density would vary inversely as the square of the distance at other target distances.

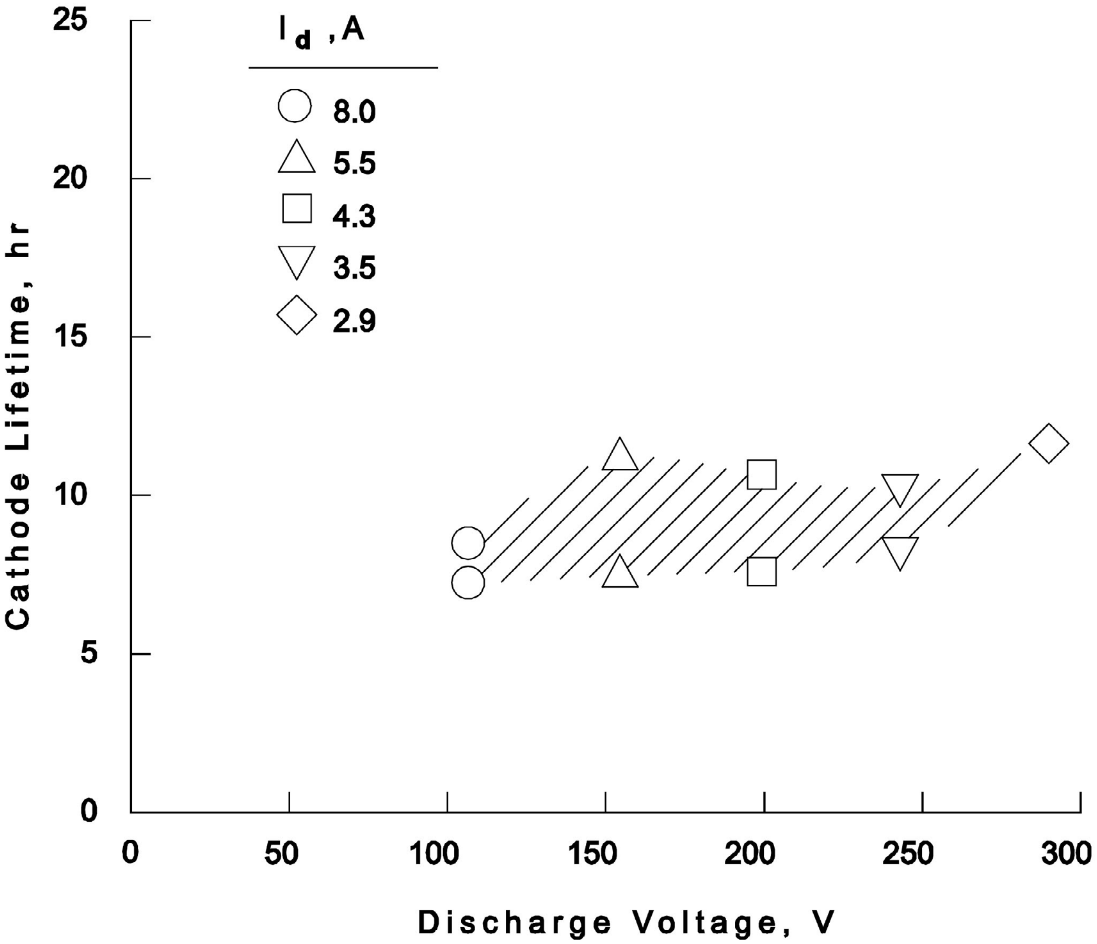

Figure 6-1. Cathode lifetimes using oxygen.

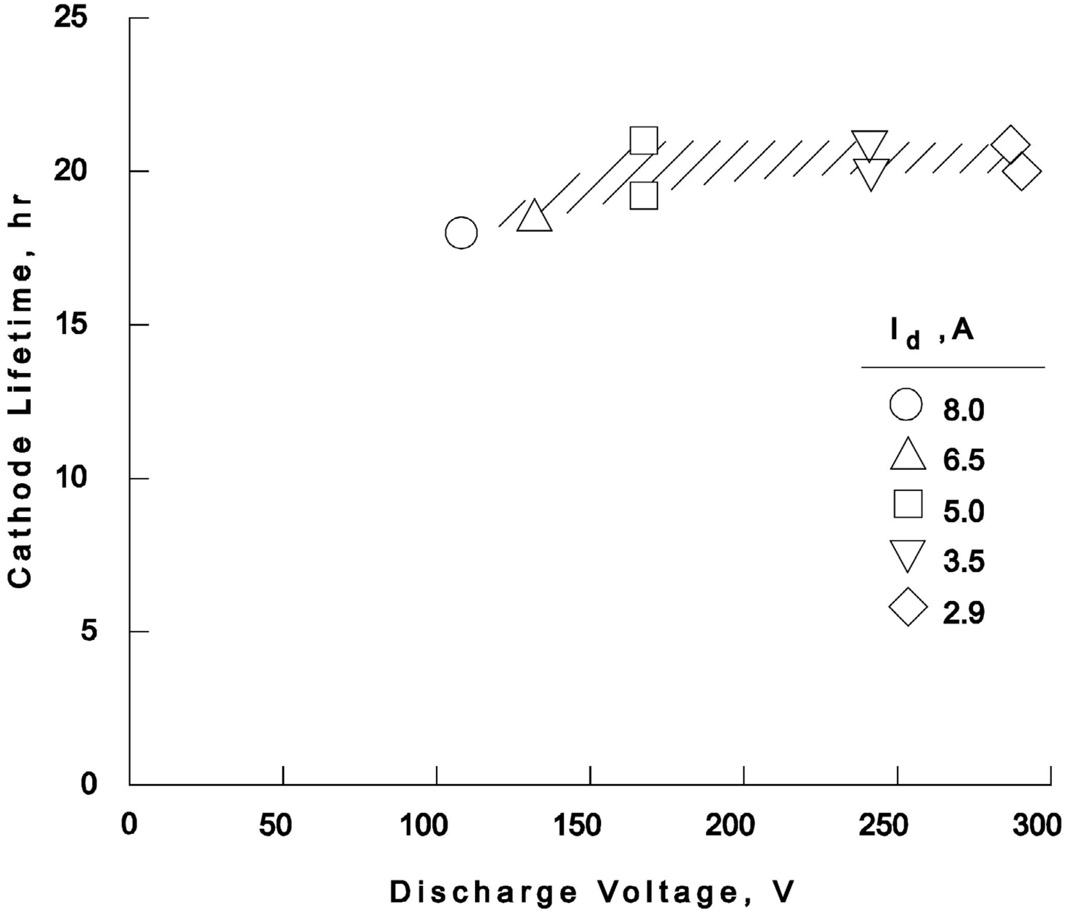

Figure 6-2. Cathode lifetimes using nitrogen.

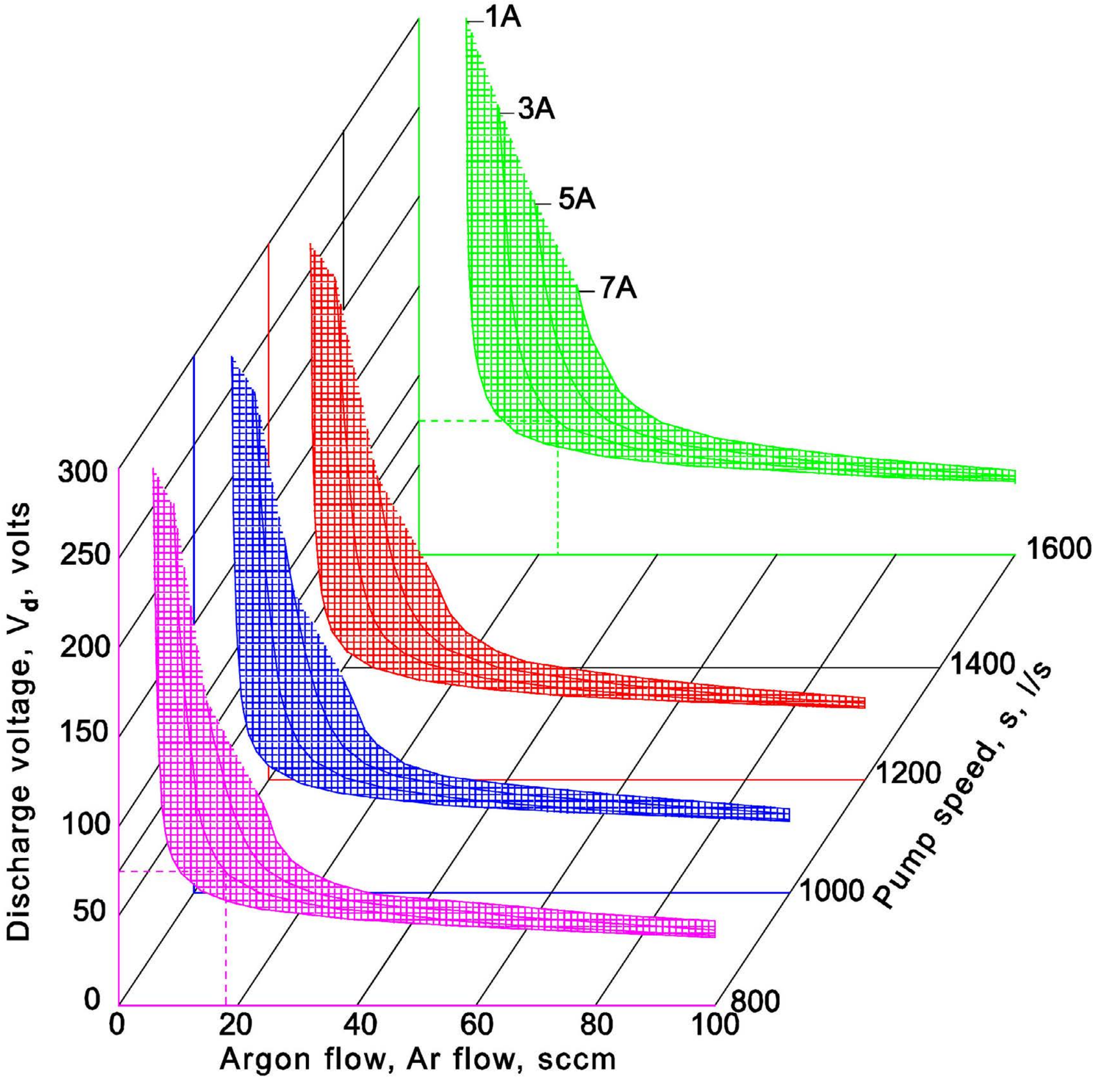

Figure 6-3. Range of operation for the KRI® eH1000F ion source at various pump speeds, using argon.

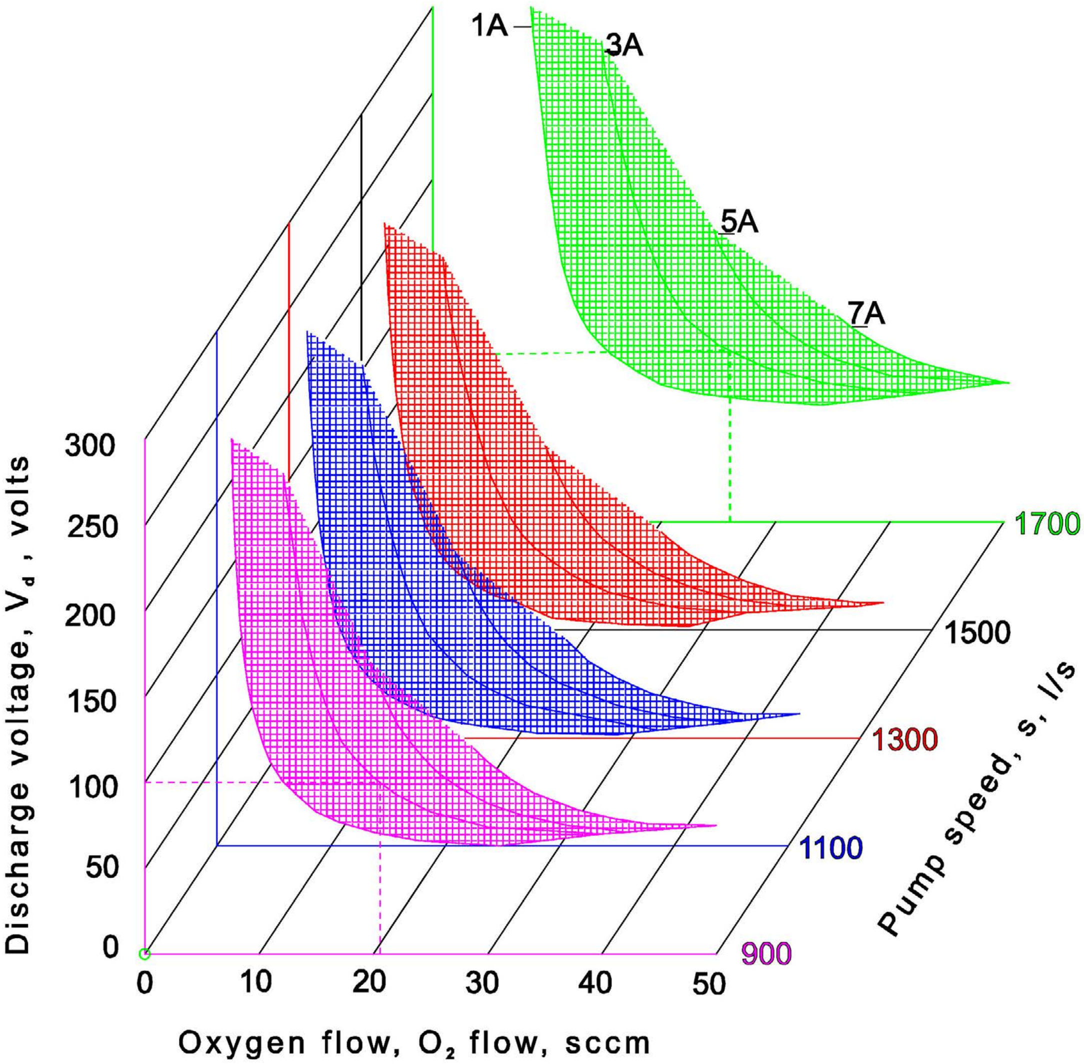

Figure 6-4. Range of operation for the KRI® eH1000F ion source at various pump speeds, using oxygen.

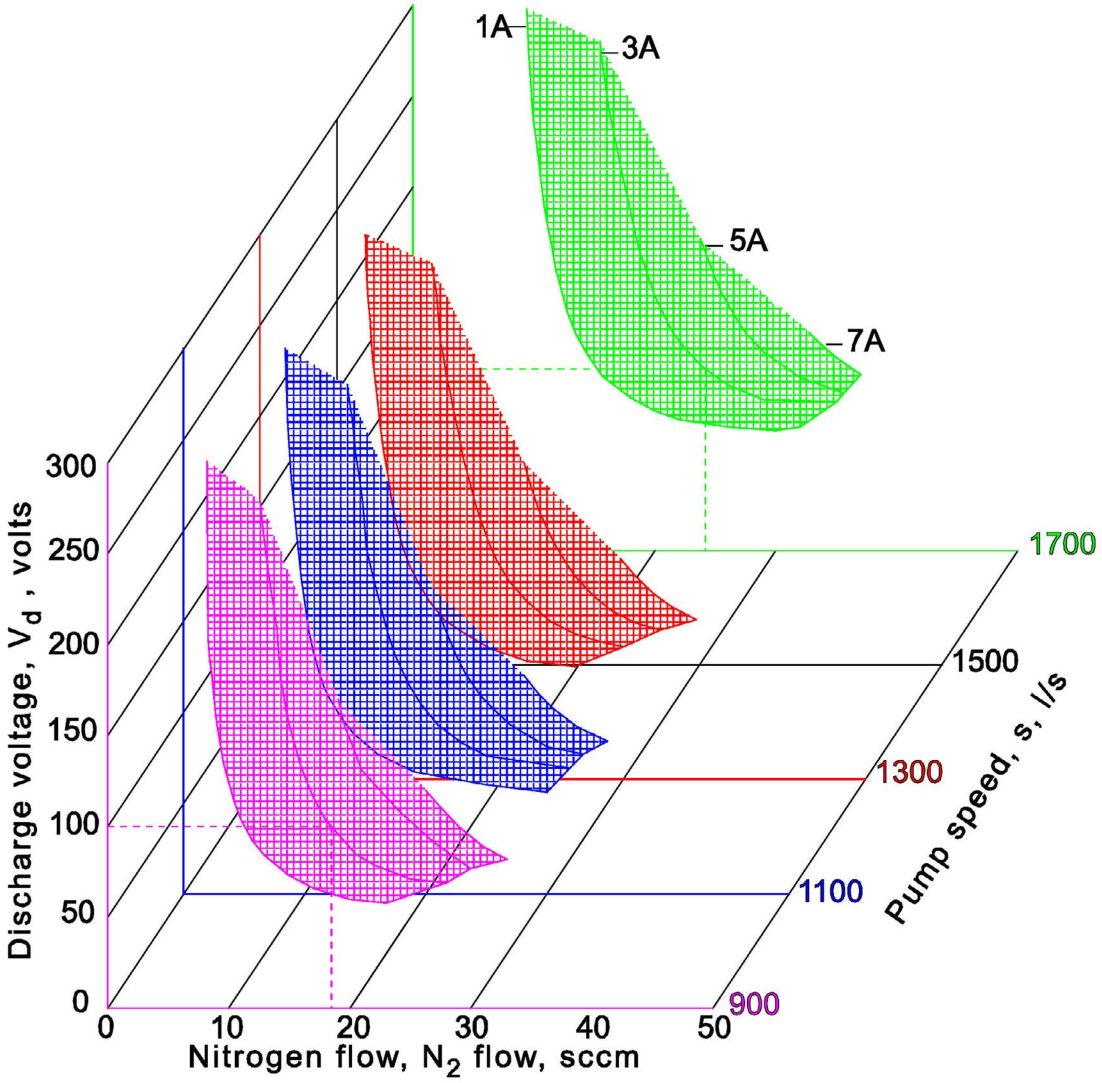

Figure 6-5. Range of operation for the KRI® eH1000F ion source at various pump speeds, using nitrogen.

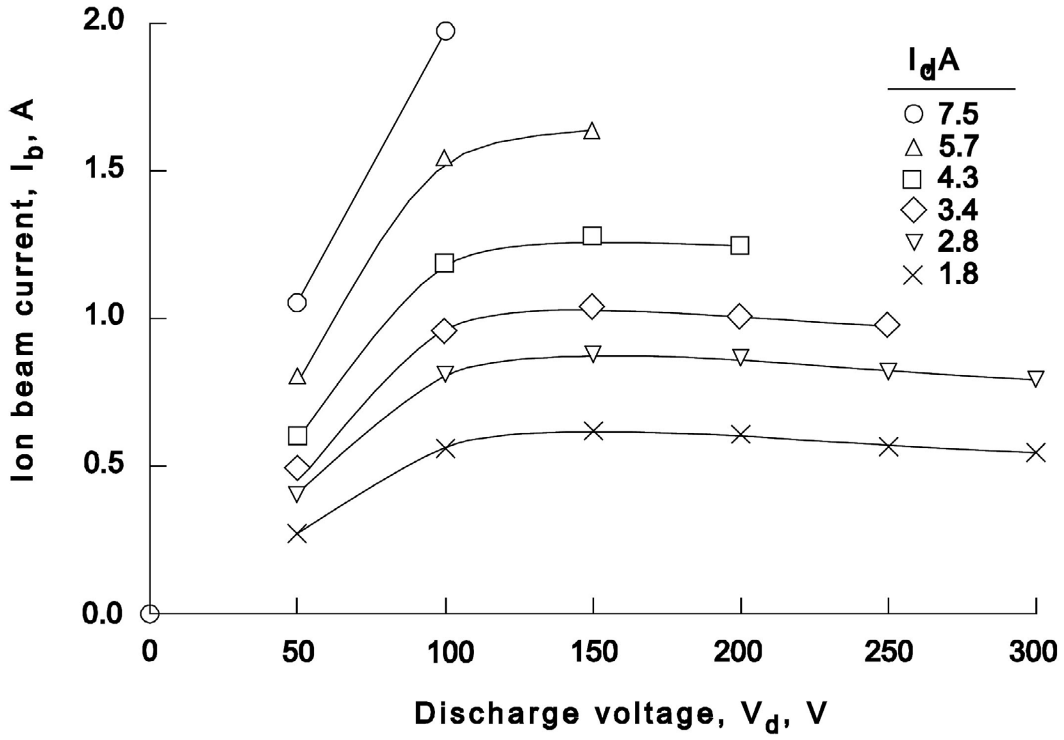

Figure 6-6. Variation of ion beam current with discharge voltage at various discharge currents, using argon.

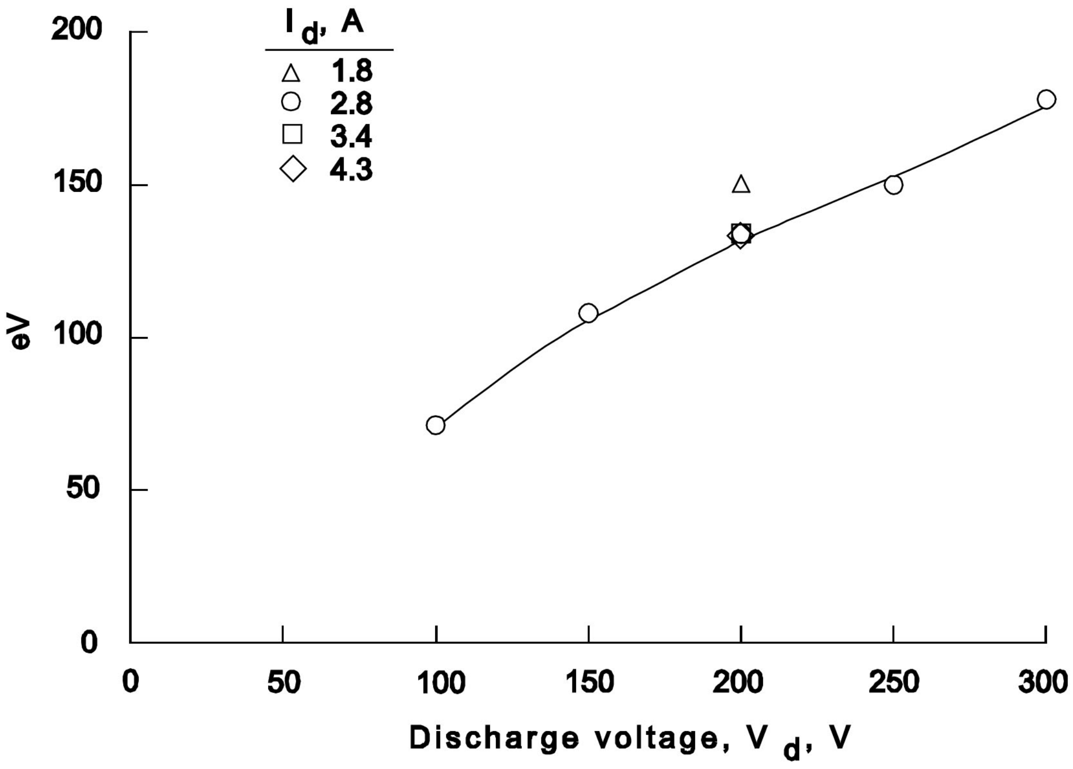

Figure 6-7. Mean ion energy with variation in discharge voltage.

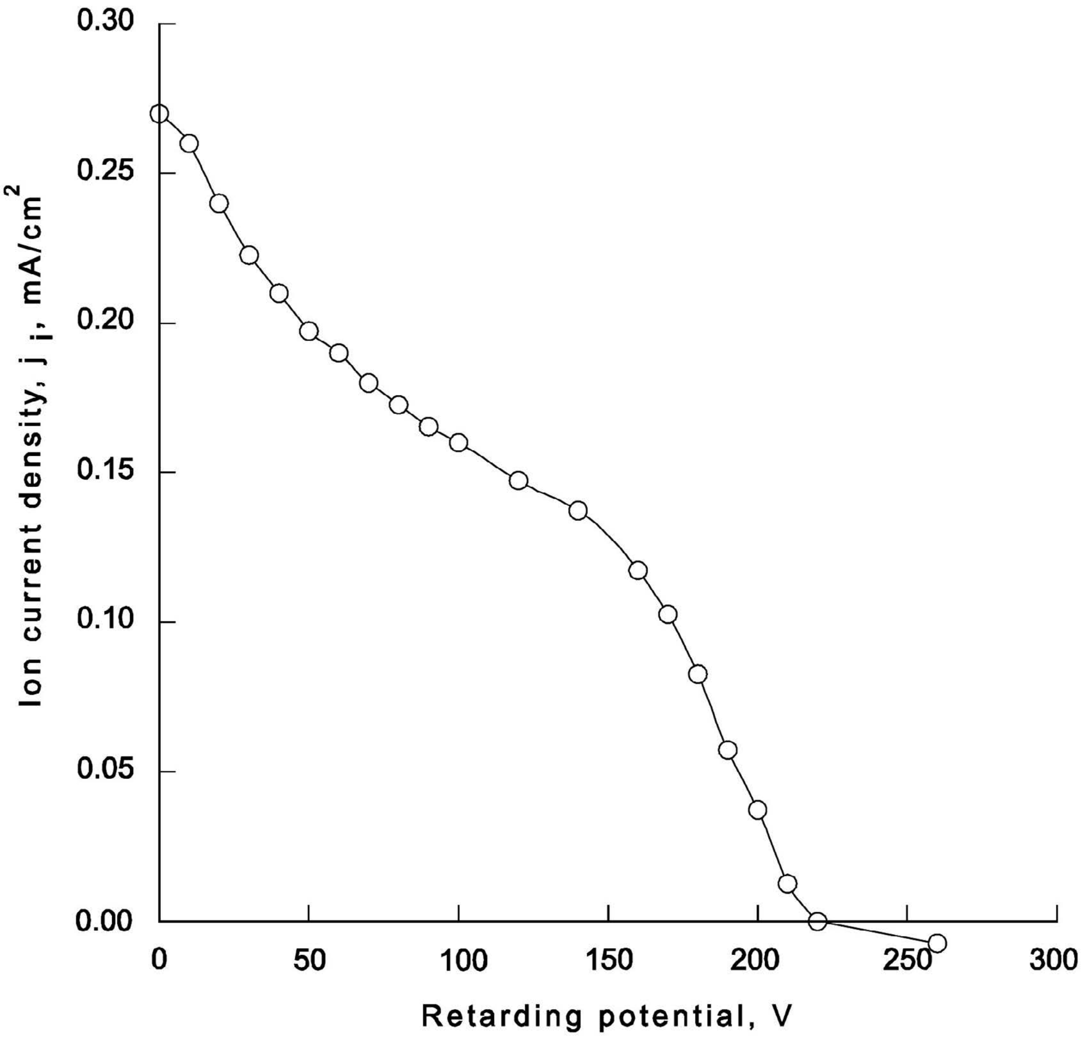

Figure 6-8. Retarding potential probe analysis of the ion beam at a discharge voltage and current of 200 V and 2.8 A.

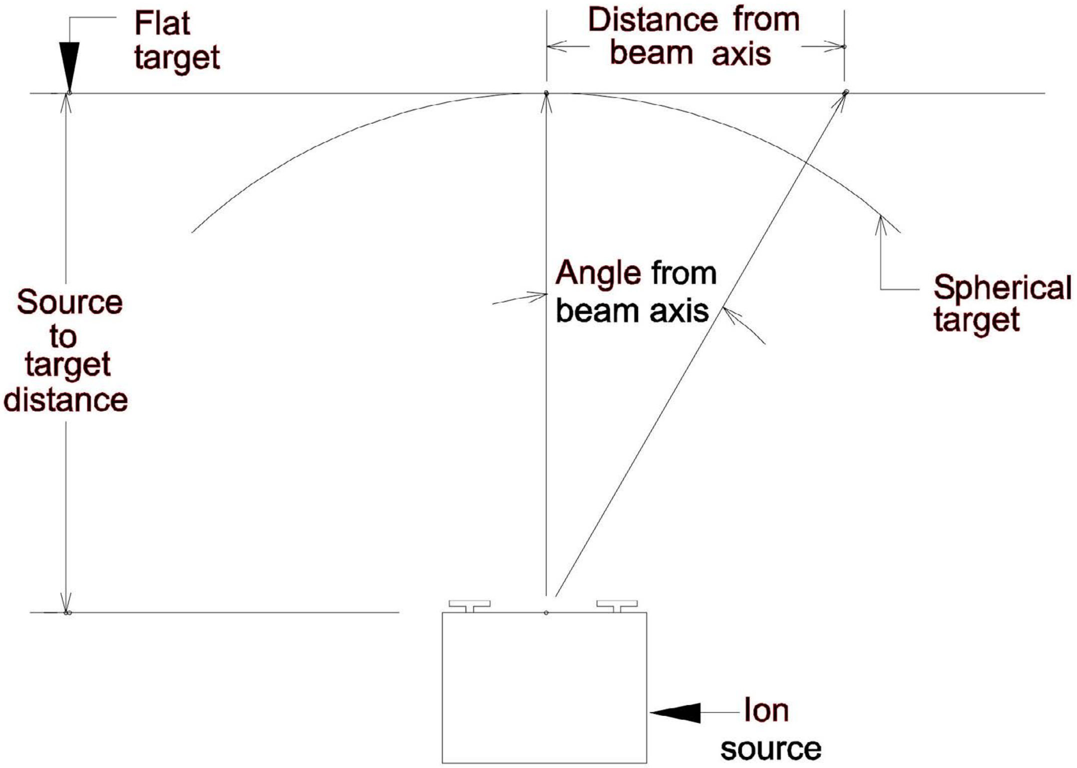

Figure 6-9. Spherical and flat target configurations.

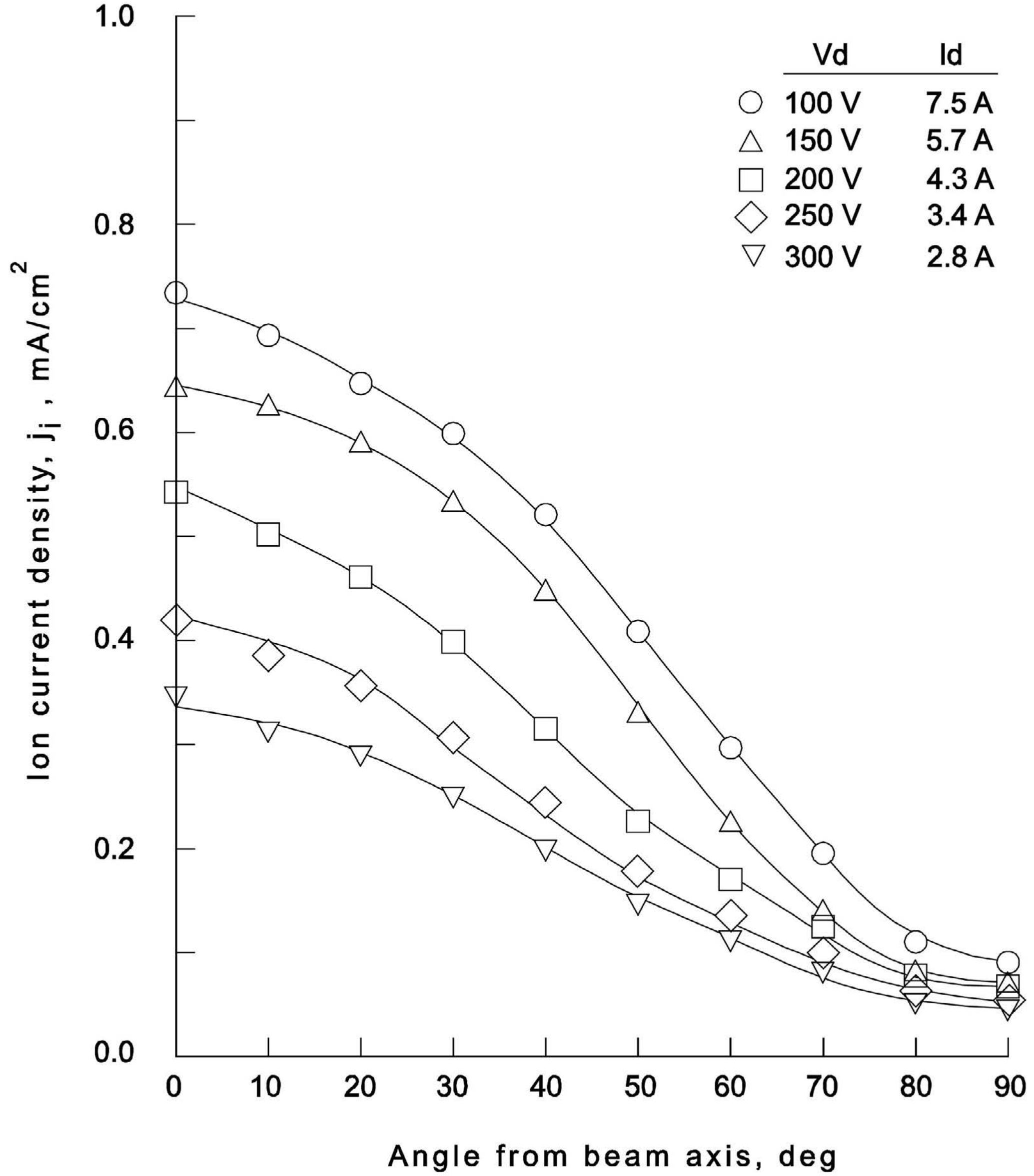

Figure 6-10. Spherical ion current density profiles for the KRI eH1000F ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is argon.

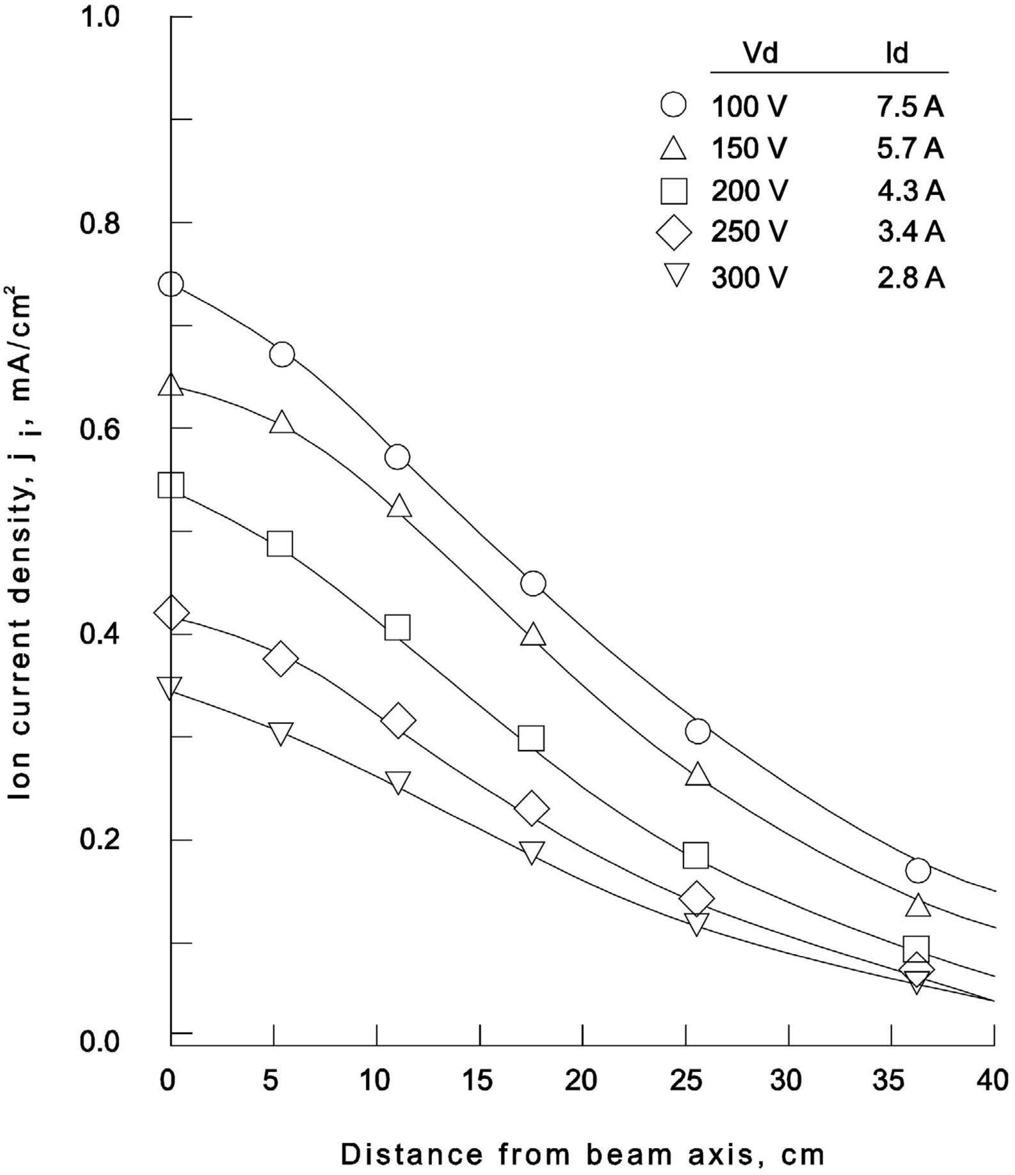

Figure 6-11. Flat target ion current density profiles for the KRI eH1000F ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is argon.

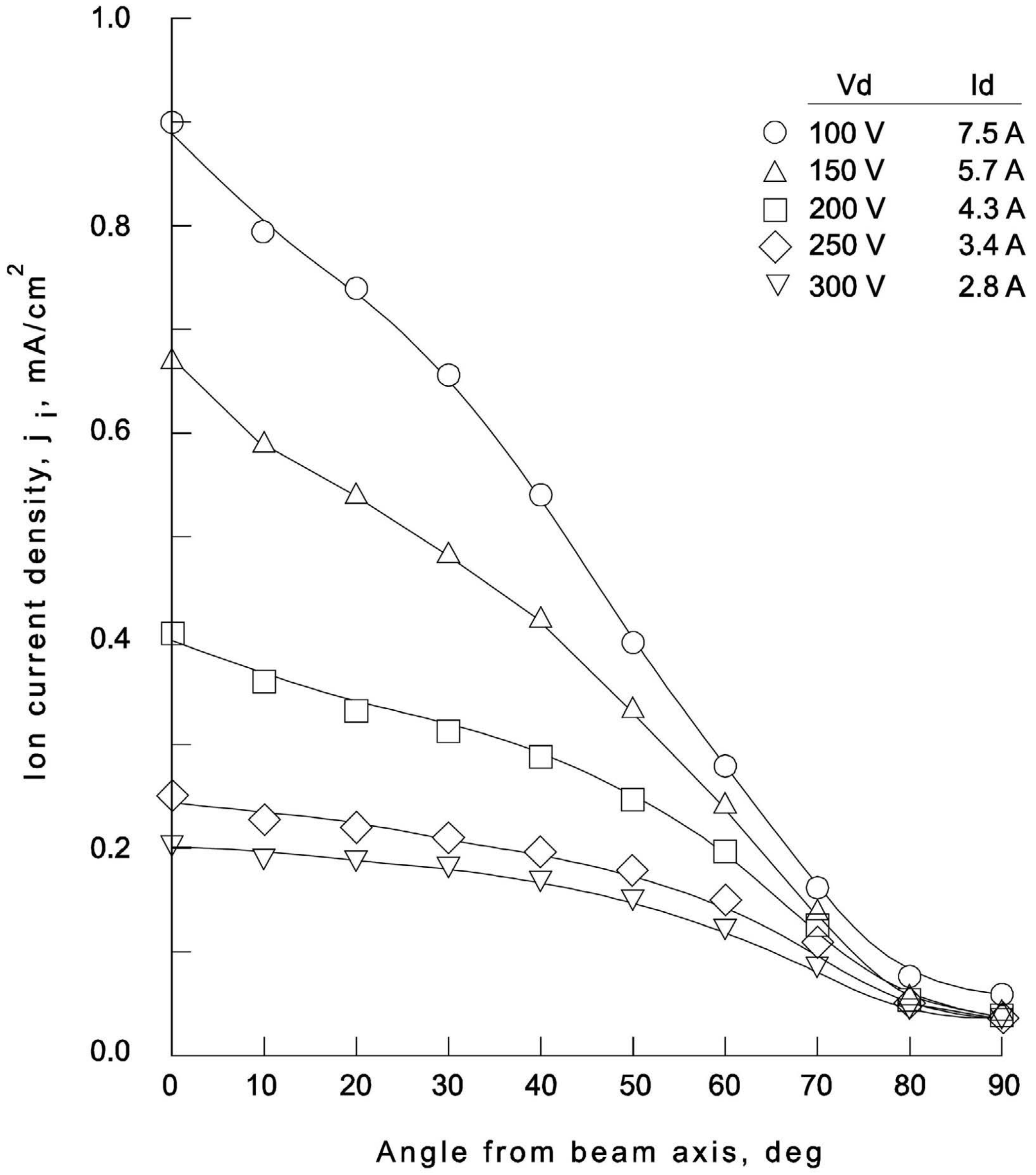

Figure 6-12. Spherical ion current density profiles for the KRI eH1000F ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is oxygen.

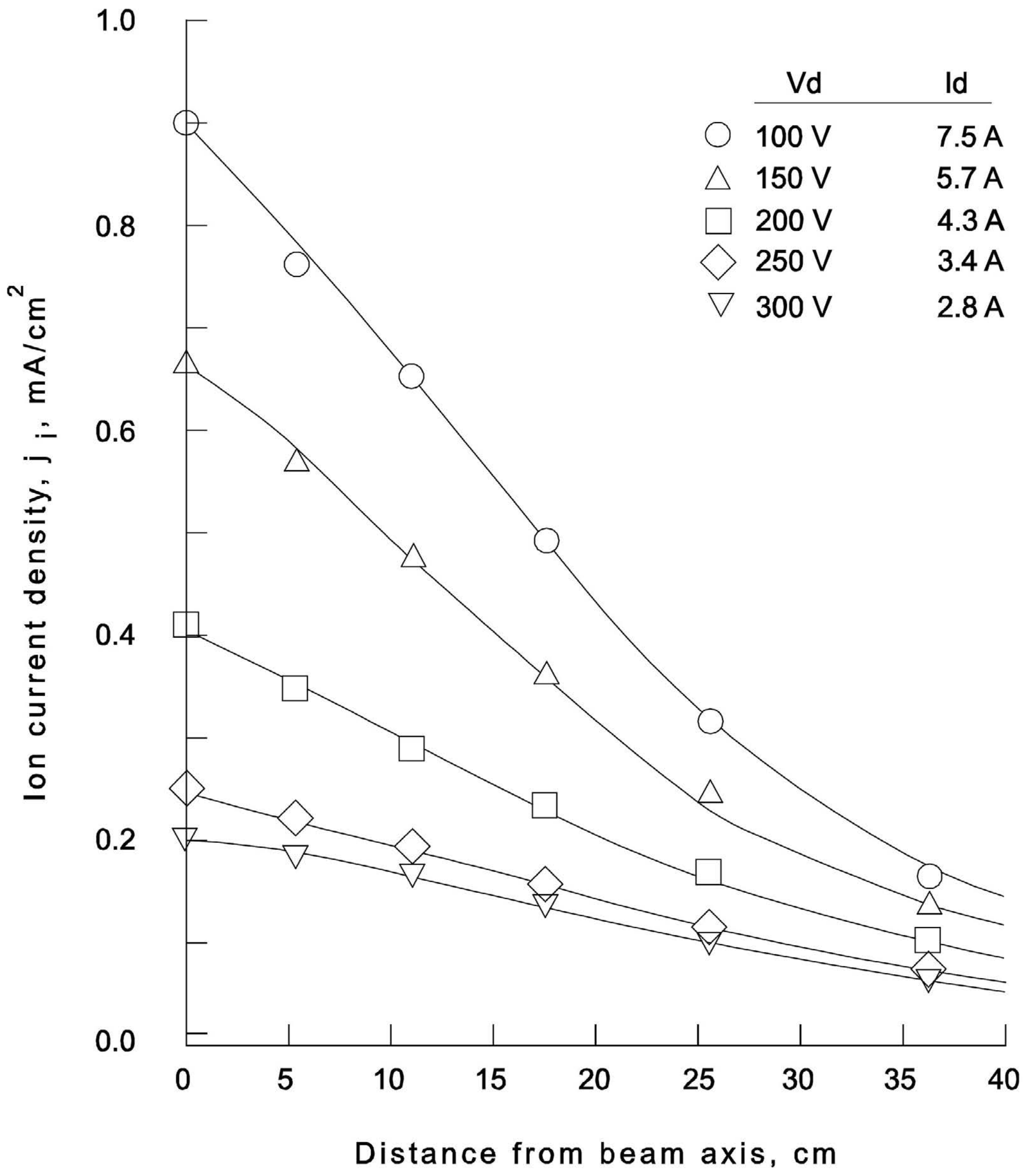

Figure 6-13. Flat target ion current density profiles for the KRI eH1000F ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is oxygen.

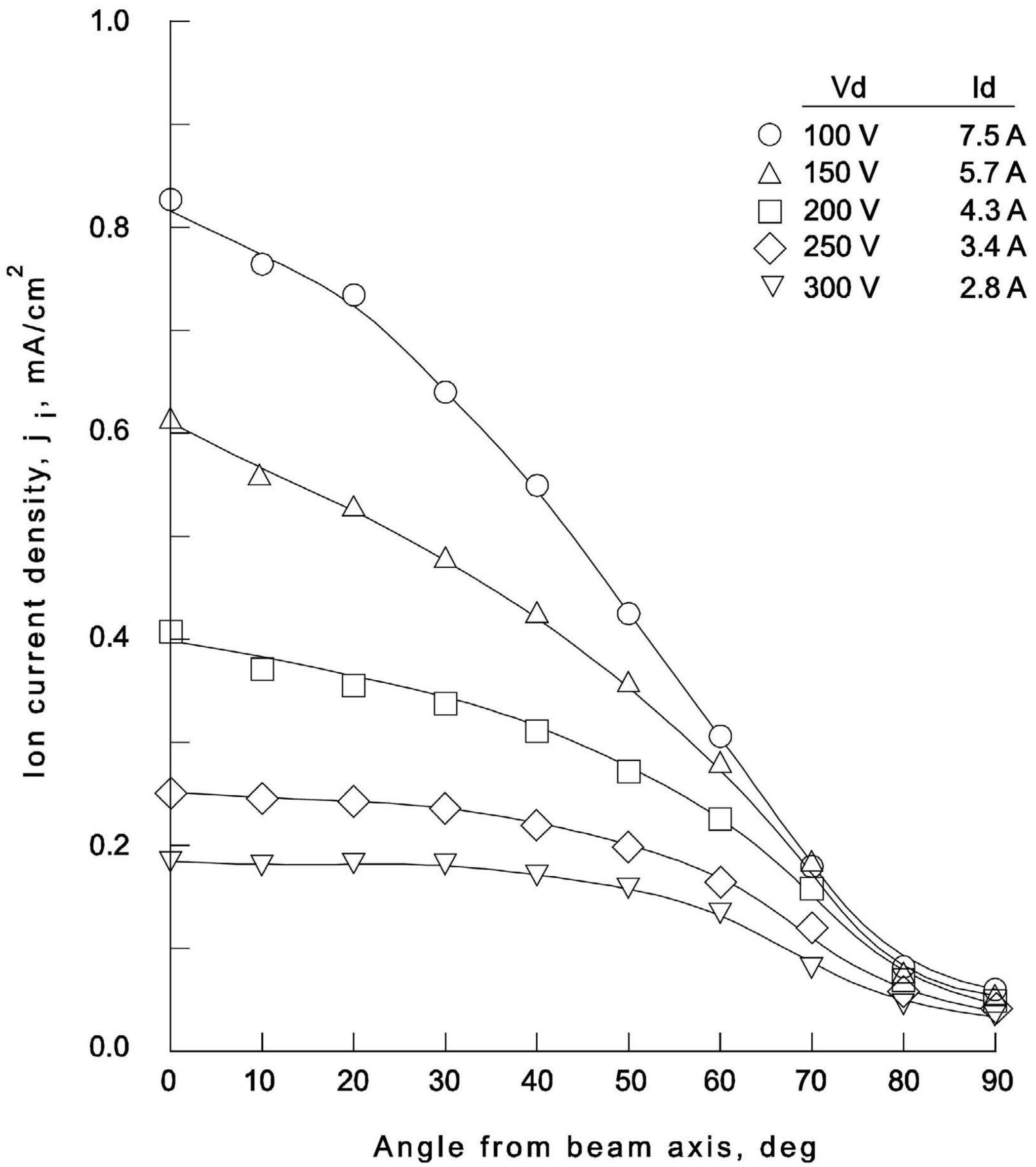

Figure 6-14. Spherical ion current density profiles for the KRI eH1000F ion source with the source at the center of the sphere. Source to target distance is 30 cm (12 in.). The working gas is nitrogen.

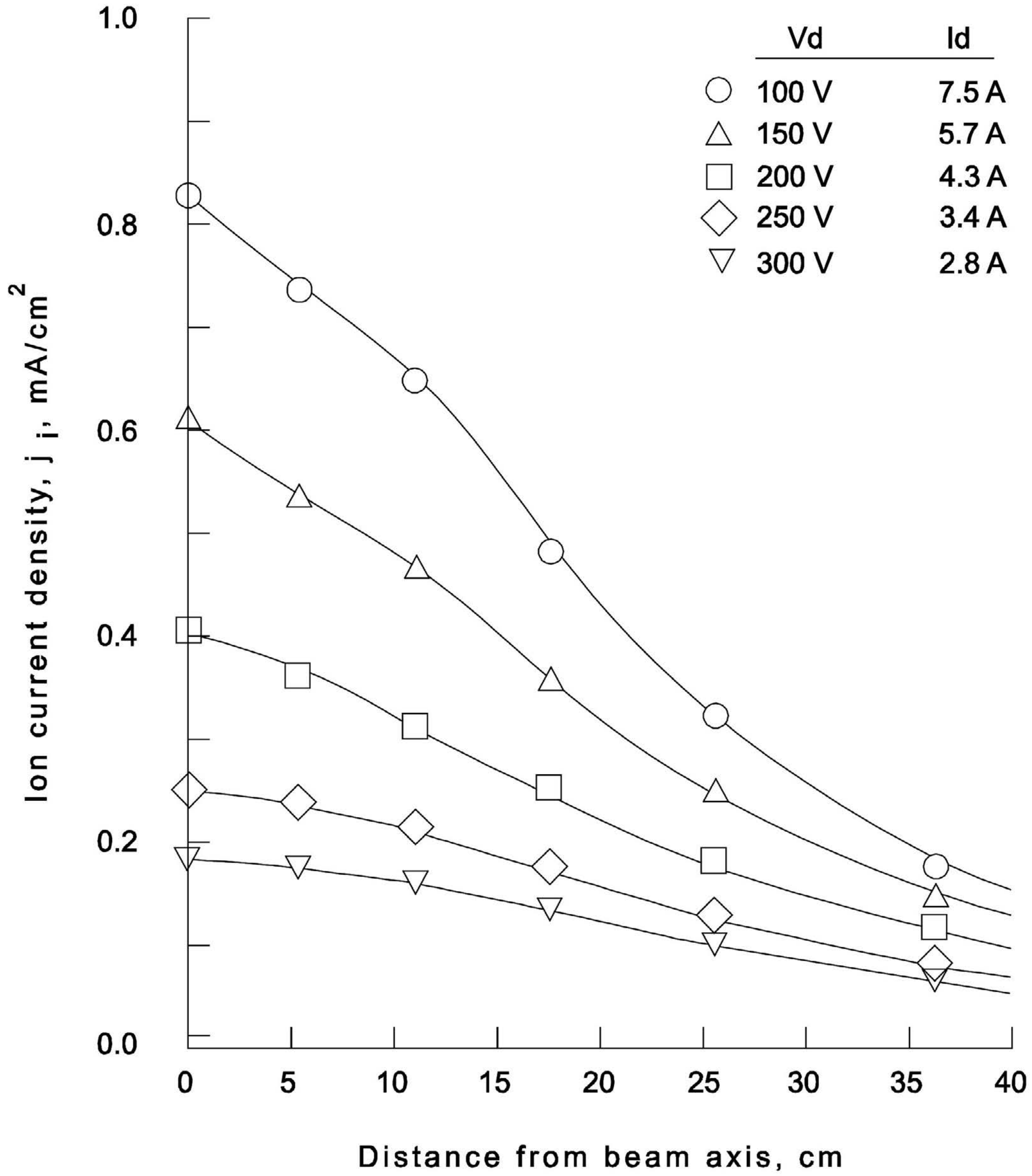

Figure 6-15. Flat target ion current density profiles for the KRI eH1000F ion source. Source to target distance is 30 cm (12 in.) and normal to beam axis. The working gas is nitrogen.

7. MAINTENANCE

Before maintenance steps are carried out, make sure the controllers 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. Fingertightening should be adequate for most threaded parts. Wrenches should be used only when there is unusual resistance. The fasteners 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

⚠ **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 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. Caution source may still remain too hot to touch. The assembled ion source is shown in Figure 7-1.

7.2.1 Filament Cathode

⚠ **WARNING:**
Source may still remain too hot to touch.

Periodically a filament will break and require replacement. A filament replacement schedule can be determined and implemented to prevent the cathode from breaking during a run. An additional set of cathode supports have been provided in addition to a cathode jig, these supports and cathode jig are shown in Figure 7-2. A spare cathode can be attached to the cathode sup-ports and installed in the cathode jig so that once the filament being used on the ion source breaks, the cathode and supports can be replaced quickly to minimize down time. Use caution when removing the cathode supports, parts may still remain too hot to touch. The cathode supports can be cleaned using an abrasive pad to remove any sputtered material or non-conductive oxides. Filament cathode fabrication can be found in Section 7.2.6.

> **WARNING:**
> Use caution when removing the cathode supports. Parts may still remain too hot to touch.

7.2.2 Modular Anode Assembly

Remove the two cathode supports and cathode as shown in Figure 7-3. Remove the two acorn nuts from the ion source front plate and using the two handles attached to the front plate, gently separate the anode module from the main module, Figure 7-3. The modular anode can now be removed from the main module. Place the anode module onto a clean working surface in the orientation shown in Figure 7-4. Remove the three 1/4-20 gold plated socket head cap screws shown in Figure 7-4 that attach the gas distributor assembly to the front plate and place the gas distributor assembly with the anode facing down on the work surface (Figure 7-5). Next remove the three gold plated 10-32 hex nuts, washers and 10-32M insulators illustrated in Figure 7-5. The gas distributor assembly may now be removed exposing the additional four 10-32M insulators and gas reflector that need to be removed (Figure 7-6). 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 (Figure 7-7). 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.

7.2.2.1 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.

7.2.2.2 Anode Connector

The anode connector is shown in Figure 7-8. 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. The beaded wire that connects the anode connector to the connector body should also be inspected for damage or coated insulators.

7.2.3 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 nitrogen and other 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. Removal of the reflector is outlined in Section 7.2.2.

7.2.4 Cathode Connector Insulators

Located within the ion source are ¼-20 insulators that are used to isolate the filament cathode from grounded hardware. If these insulators become broken or coated with conductive coatings they must be replaced. A continuity check can be made to determine if these insulators need replacement. Before this measurement is made the electrical cable that connects from the power supplies to the feedthrough should be disconnected. Remove the cathode from the cathode supports. Using an ohmmeter, touch one probe tip to the grounded shell of the main module. Touch the other probe tip to one cathode support, then, touch the probe tip to the other cathode support. Any resistance other than infinite is evidence that these insulators need inspection. Inspection and replacement of these ¼-20 insulators can be done once the modular anode assembly has been separated from the main module. Once the modular anode assembly has been removed from the ion source the cathode connectors can be inspected. A continuity check can be made from the connectors to the ion source back plate or other grounded hardware. Any resistance other than maximum is evidence that the insulators need replacement. The beaded wires that connect from the cathode connectors to the connector body should also be inspected to make sure that these beads are not coated or broken, causing a cathode to ground short.

7.2.5 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.

7.2.6 Cathode Fabrication

7.2.6.1 Required Tools and Material

The following tools and material are required to fabricate EH-1000 neutralizer filaments: 0.05 cm (0.020 inch) diameter tungsten wire 38.10 cm (15 inches) long, 0.40 cm (0.157 inch) diameter metal rod (or #22 drill bit), 0.64 cm (1/4 inch) diameter metal rod and wire cutters.

7.2.6.2 Fabrication

Measure 6.35 cm (2.500 inches) from one end of the 38.10 cm (15 inch) tungsten wire. At this measurement point begin to coil the 31.75 cm (12 1/2 inch) end of the tungsten wire 16 times around the 0.40 cm (0.157 inch) diameter rod (Figure 7-11). Each coil around the 0.40 cm (0.157 inch) rod should rest against the previous coil in a tight pattern. Figure 7-12 shows the tungsten wire wrapped around the forming rod. When tension on the wire is released it will uncoil 1 1/4 turns and the two ends of the wire should rest 90° apart. With the coiled wire still on the 0.40 cm (0.157 inch) diameter rod gently bend each end of the wire parallel to the 0.40 cm (0.157 inch) rod (Figure 7-13). All of this bend should take place at the last coil on each end. Measure 5.08 cm (2.0 inches) from the last coil on each end and cut at this location. Remove the filament from the rod. Approximately 1.27 cm (0.500 inches) from each end of the wire, bend the wire around the 0.64 cm

(1/4 inch) rod in a clockwise direction (Figure 7-14). Figure 7-15 shows the completed cathode. The correct coil spacing between the coils will be established when the cathode is installed in the cathode supports while installed in the cathode jig or ion source.

7.2.7 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**
Anode, inert gas version	EH10-14
Anode, reactive gas version	EH10-14L
Magnet, inert gas version	MS09-01
Magnet, reactive gas version	MS09-01L
Reflector, pyrolytic graphite, inert gas	EH10-12-C
Reflector, stainless steel, reactive gas	EH10-12-S
Reflector, tantalum	EH10-12-TA
Reflector, titanium	EH10-12-TI

Figure 7-1. Assembled ion source.

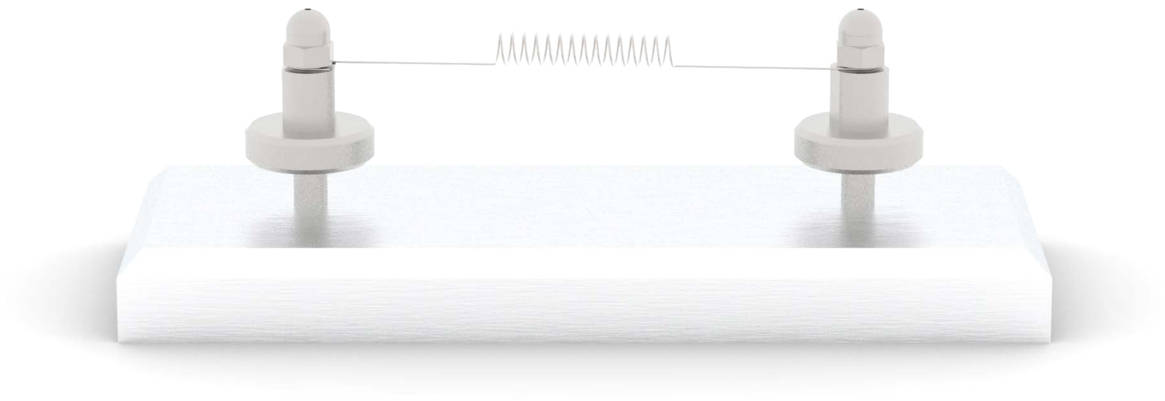

Figure 7-2. Filament cathode installed on the cathode jig.

Figure 7-3. Cathode, cathode supports, and anode module removed from the main module.

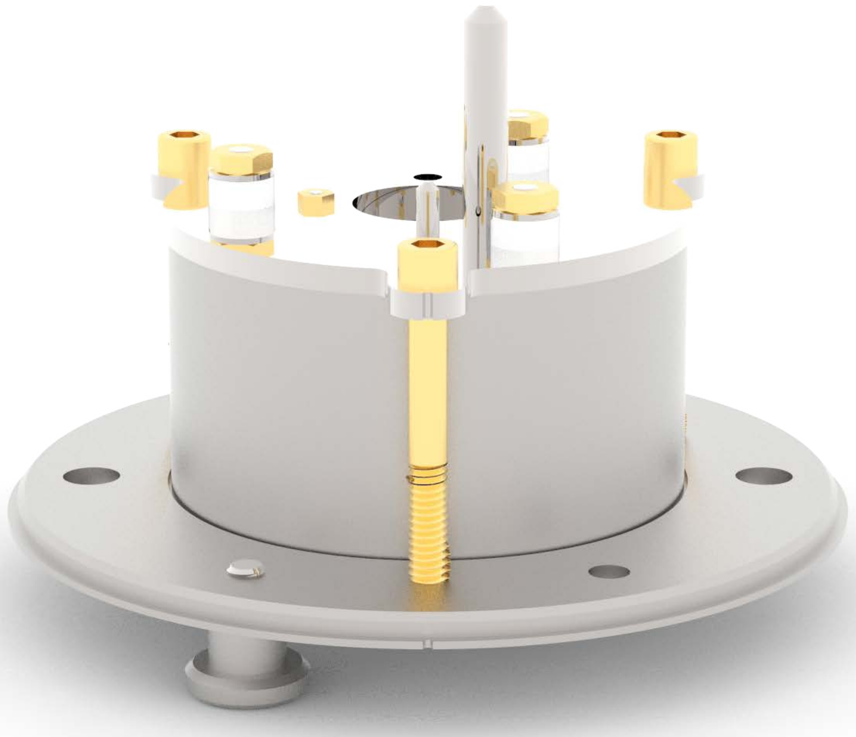

Figure 7-4. Modular anode assembly.

Figure 7-5. Gas distributor assembly.

Figure 7-6. Gas reflector and 10-32M insulators.

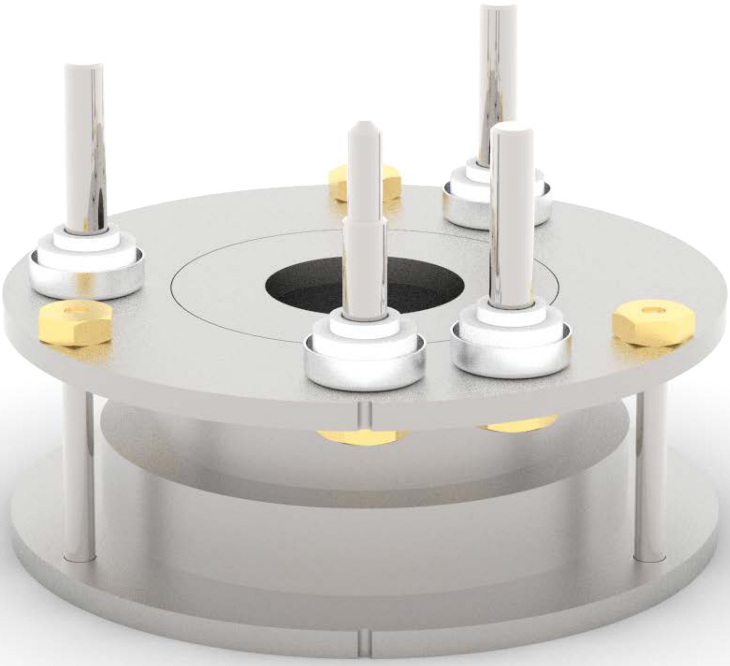

Figure 7-7. Anode support, 10-32M insulators, and 10-32 sputter cups.

Figure 7-8. Anode and 6-32 bolts.

Figure 7-9. Assembled ion source.

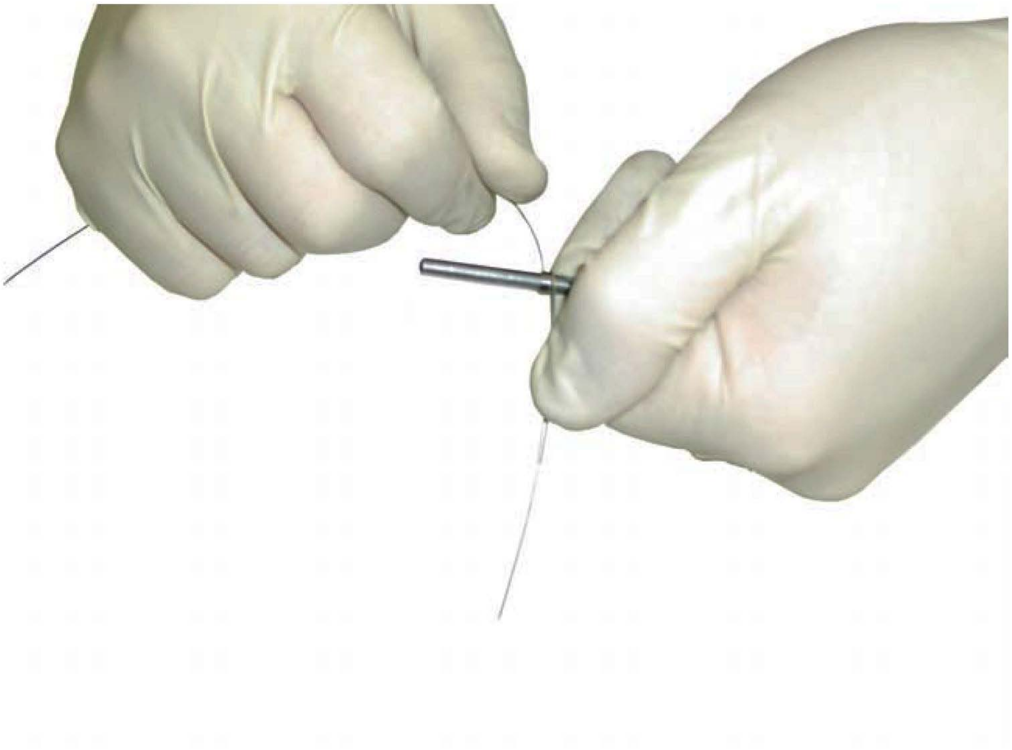

Figure 7-10. Forming filament coils by wrapping tungsten wire around form.

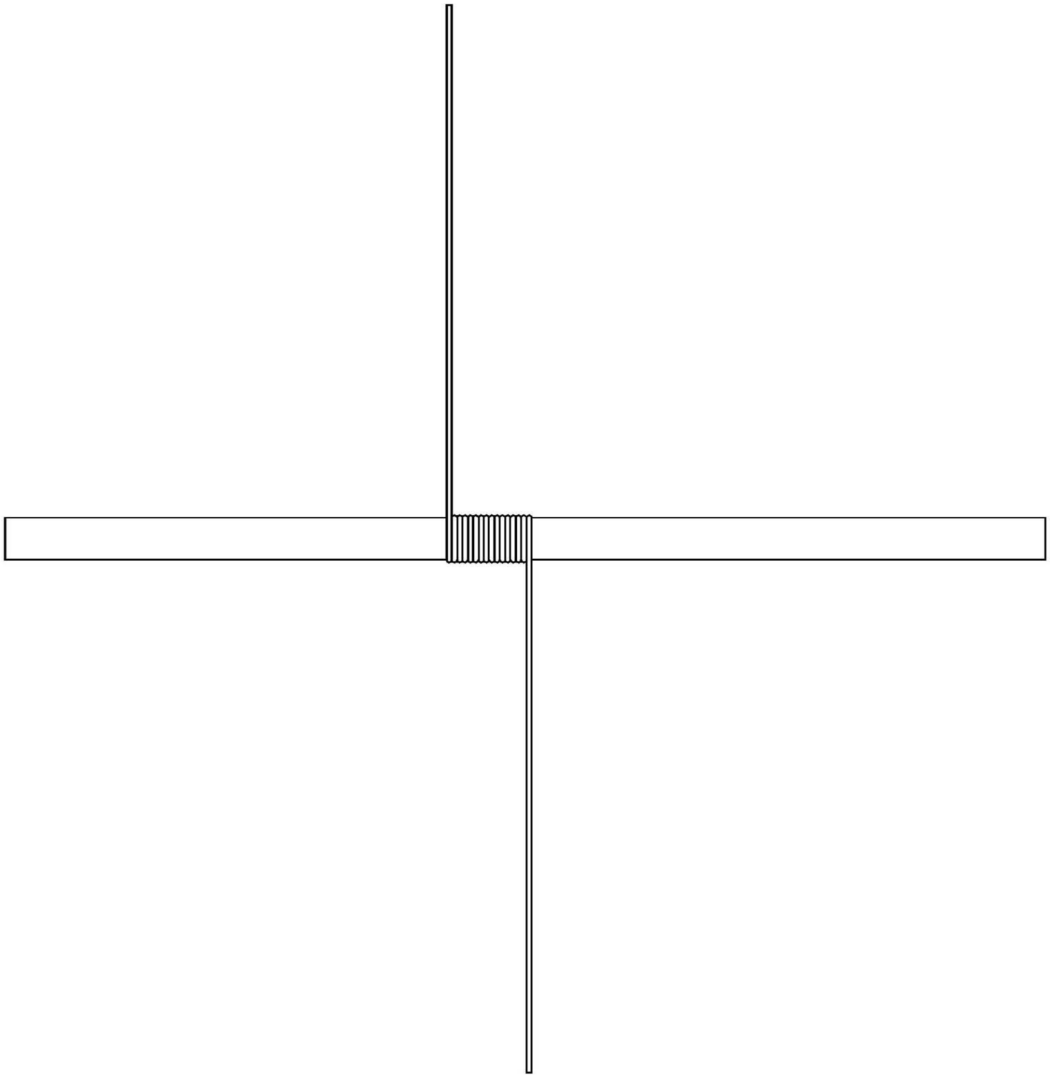

Figure 7-11. View of cathode coils on form.

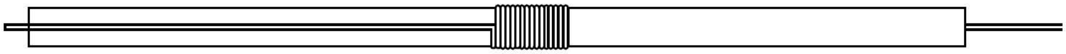

Figure 7-12. Bending tungsten wire ends parallel to the form.

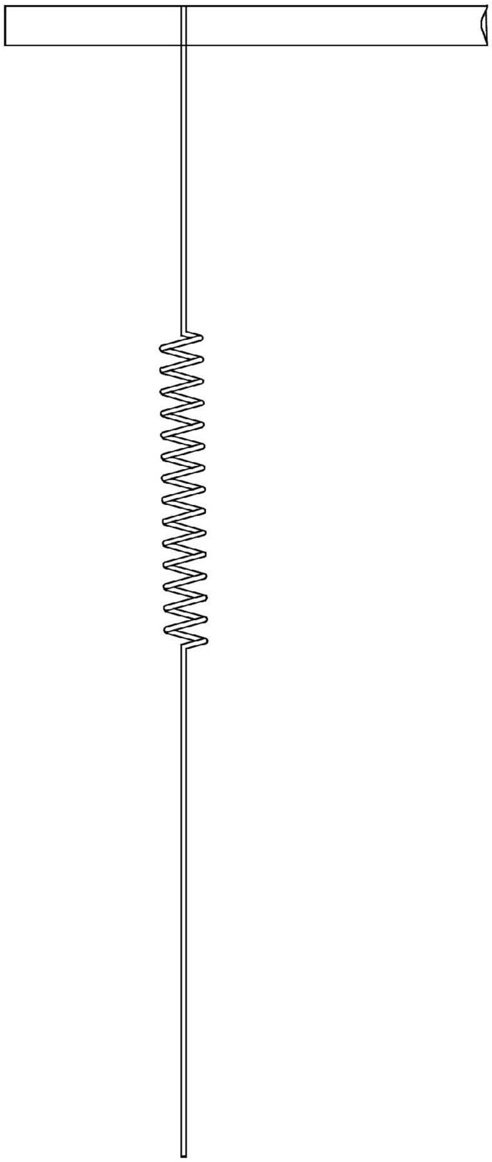

Figure 7-13. Forming the ends of the filament cathode.

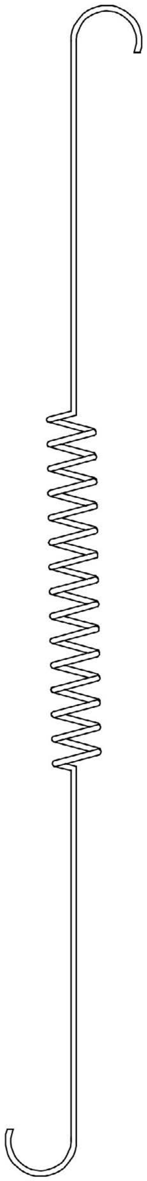

Figure 7-14. Completed filament cathode.

This Page is Intentionally Blank

8. DIAGNOSTICS

8.1 General

The following information is intended to facilitate troubleshooting and repair of the eH1000F 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 herein.

⚠ **Warning:**
Power must be removed from the controllers prior to performing maintenance on the eH1000F ion source.

8.2 eH1000F

In the event that abnormalities occur in the starting or operation of the eH1000F ion source, an ohmmeter check of the source can be done at the electrical feed-through 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 eH1000F ion source, electrical feedthrough or the vacuum cable. If the ohmmeter reads maximum when the ohmmeter is connected from the electrical feed-through 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 nonconductive 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 eH1000F ion source.

Table 8-1. Diagnostic Table

Symptom	Possible Cause	Correction
Inability to start a discharge (ion source), discharge voltage normal, no discharge current, cathode normal	• Broken filament	• Replace cathode
	• Low gas flow	• Increase gas flow, and/or calibrate flow controller
	• Poor electrical connections	• Check all electrical connections to insure electrical circuit is complete and the electrical connections are reliable
	• Insulating layer on anode	• 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	• Replace coated insulators or remove any debris
	• Incorrect reflector installed for the gas in use	• Install the correct reflector
No cathode current or cathode emission	• Broken filament cathode	• Replace cathode

This Page is Intentionally Blank

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.

This Page is Intentionally Blank

10. REFERENCES

1. H.R. Kaufman and R.S. Robinson, *Operation of Broad-Beam Sources*, Commonwealth Scientific Corporation, Alexandria, Virginia, 1987.

2. H.R. Kaufman, R.S. Robinson, and W.E. Hughes, *Characteristics, Capabilities, and Applications of Broad-Beam Sources*, Commonwealth Scientific Corporation, Alexandria, Virginia, 1987.

3. J.M.E. Harper, J.J. Cuomo, and H.R. Kaufman, “Technology and Applications of Broad-Beam Ion Sources Used in Sputtering. Part II. Applications,” *Journal of Vacuum Science and Technology*, Vol. 21, pages 737-756, Sept./Oct. 1982.

4. J.M.E. Harper, J.J. Cuomo, R.J. Gambino, and H.R. Kaufman, “Modification of Thin Film Properties by Ion Bombardment During Deposition,” pp 127-162 in *Ion Bombardment Modification of Surfaces: Fundamentals and Applications* (O. Auciello and R. Kelly, eds.), Elsevier Science Publishers, Amsterdam, 1984.

5. J.J. Cuomo, S.M. Rossnagel, and H.R. Kaufman, eds., *Handbook of Ion Beam Processing Technology*, Noyes Publications, Park Ridge, New Jersey, 1989.

6. Ch. Huth, H.-C. Scheer, B. Schneemann, and H.P. Stoll, “Divergence Measurements for Characterization of the Micropatterning Quality of Broad Ion Beams,” *Journal of Vacuum Science and Technology*, Vol. A8, No. 6, pages 4001-4010, Nov./Dec. 1990.

7. J.R. Kahn, H.R. Kaufman, C.A. Phillips, and R.S. Robinson, “Probe for Measuring Ion Beam Angular Distribution,” *Journal of Vacuum Science and Technology*, Vol. A14, No. 4, pages 2106-2112, July/Aug. 1996.