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## Instruction Manual Appendage Ion Pumps



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**Instruction Manual  
Appendage Sputter - Ion Pumps**

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# 1 Principle of Operation

## A Overview

The sputter-ion pump operates on the principle of the Penning cold-cathode discharge. In this type of pump, a combination of magnetic and electric fields sustains a discharge in a structure such as shown in Figure 1. In the most common configuration, an array of cylindrical anode cells is placed between parallel cathode plates made of titanium. A positive voltage of between 3000 volts and 7000 volts is applied to the anode and a magnetic field of between 1000 and 2000 gauss is applied parallel to axis of the anode cells. At pressures below approximately a millitorr, a cloud of spiraling electrons is captured inside the anode cells. These electrons collide with residual gas molecules to form positive ions. The gas molecules, being heavier and of opposite charge than the electrons, accelerate out of the anode cell toward the cathode plates. When they reach the cathode, the ions release their energy, causing:

1. Some of the titanium atoms to be released (sputtering). This chemically active material is deposited onto surfaces nearby. It acts as a getter until saturated.
2. Secondary electrons to be released, which get incorporated into sustaining the discharge inside the anode cells.
3. Chemical reaction with the titanium, if the gas ion is an active, and/or burial in the cathode for both active and noble gases.

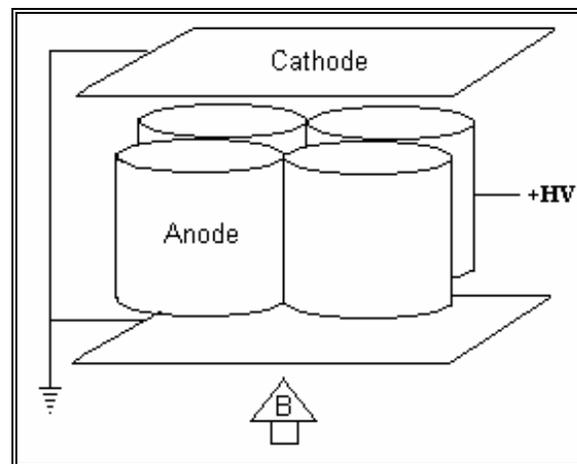


Figure 1 Diode Sputter-Ion Pump Configuration

## **B Choice of Pumping Element Technology**

### **Diode Element**

In the overview of Figure 1 above the most common configuration of sputter-ion pumps, the diode, is described. Both cathodes are made of titanium and the structure is simple and rugged. For most applications, where active and/or residual gases comprise the main load on the pump, this configuration works well. This applies to Nitrogen, Oxygen, Water Vapor, Carbon Dioxide and like chemically active gases.

The diode pump can develop problems with noble gases such as argon, either as the main gas load or as the result of sustained air leaks (argon comprises approximately 1% of air). Since argon is chemically neutral it is pumped by burial only. After prolonged operation, some of the previously buried argon gets re-emitted due to the sputtering action of the pump. The pressure rise causes additional sputtering, which causes additional argon to be re-emitted, etc., and the pressure rises rapidly, to about  $10^{-4}$  torr. At this point, as the electrical discharge changes into a more diffuse mode, the argon gets slowly pumped into other areas of the pump and the pressure slowly falls over a few minutes. At a certain point, the discharge shifts back into the confined Penning mode, and the pressure falls rapidly to the base pressure of the system. This behavior, called "argon instability", continues in a periodic fashion with a period which increases as the size of argon load decreases.

## **C Typical Applications**

Because of their simplicity, cleanliness and trouble free operation at low pressures, sputter-ion pumps are especially suited for a number of applications. These include electron beam devices, ion beam devices, particle accelerators, high power vacuum tubes, semiconductor processing equipment, mass spectrometers, material research equipment and many others.

## 2 Installation

### A Preliminary Tests

The appendage sputter-ion pump arrives well protected in a package and some models are under vacuum. After carefully unpacking the pump, inspect it for signs of shipping damage. If any shipping damage is suspected, immediately contact Duniway Stockroom Corp. Before opening the copper pinch-off on vacuum processed models, it is advisable to check that it is still under vacuum. This is accomplished by properly grounding the pump, connecting the high voltage connector, and applying an operating voltage to the pump. The magnet must be in place for this test. Normally there will be a brief surge of current of less than 100 micro-amperes due to pressure rise during shipment which will dissipate rapidly. Within a brief time, the current should fall to the microamp level, corresponding to pressure of less than  $1 \times 10^{-8}$  torr. If a high current is observed, or if the current does not fall rapidly to less than a few microamps, or if no current at all is observed, the pump is probably not under vacuum. Contact Duniway Stockroom immediately.

### B Mounting Requirements

Make sure all mounting surfaces are clean. On soldered/welded pumps, the best pumping speeds are achieved with the shortest possible tube length. For UHV systems, the non-flanged pumps should be TIG welded, hydrogen brazed, or vacuum brazed. Do not use flux in UHV joints. For flanged pumps, the system should have a mounting flange which is the same as the pump flange. A new copper gasket and the set of bolts and nuts from the original closure flange are required. After installation, leak check the system. Install the magnet with the appropriate hardware.

### C Grounding Requirements

Due to the hazardous nature of the high voltage used to operate this pump, it is important that proper grounding be present at all times during pump operation. Dual grounding means are provided: The first grounding means is through the high voltage cable shield and connector shell which are connected to the control unit chassis and pump body when installed. Be sure that the "garter spring" around the pump high voltage feedthrough is in place when the high voltage connector is installed. See Figure 2 below for a view of the high voltage feedthrough and connector shell. The second grounding means is through a separate grounding cable which is connected to the case of the control unit and the grounding boss/lug on the pump case.

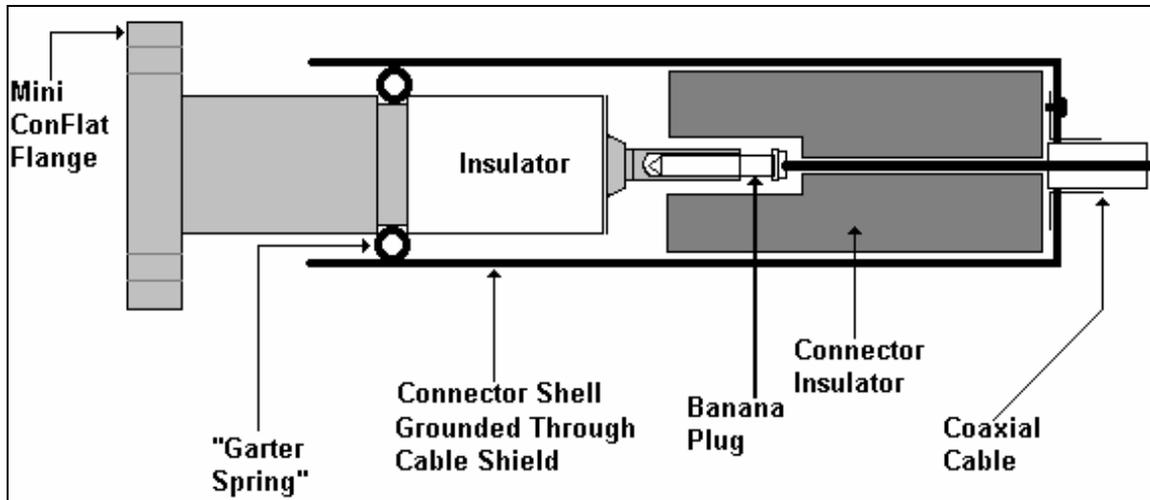
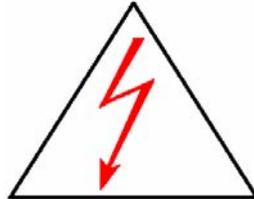


Figure 2: Feedthrough with “Garter Spring “ and Grounded Connector Shell

#### D Connecting the High Voltage Supply

Caution: The voltages utilized by sputter-ion pumps are hazardous and can cause severe injury or death if proper procedures are not followed.



The high voltage connection is provided via a coaxial cable, which has MS type connector on the control unit end and a male banana plug surrounded by a ceramic insulator and grounded metal shell on the pump end. The outer shield of the coaxial cable is grounded at both ends for safety reasons. See Figure 2 above for a sketch of the pump-end connection. When connecting the high voltage control unit to the pump, the first step is to be sure that the high voltage control unit is OFF. Then, firmly attach the control unit end of the cable to the control unit. Next, verify that the “garter spring” grounding spring is in place around the groove between the insulator and metal portion of the feedthrough. Then, slip the cylindrical connector shell over the high voltage feed through, being sure that the male banana plug of the connector engages the female receptacle of the high voltage feedthrough and that the cylindrical shell of the connector engages the “garter spring” for grounding purposes. When properly engaged, the connector is firmly in place with little room for movement.

The 2 l/s pumps use the garter spring for grounding, and the 0.2 l/s pumps use a separate ground wire. Make sure that all pumps are correctly grounded before applying high voltage.

## **E Starting the Pump**

### **1. Introduction**

Sputter-ion pumps have many advantages in simplicity, cleanliness and reliability for high and ultra-high vacuum systems. The transition from the roughing pressure to independent operation at high vacuum is referred to as “starting”. With some attention to preparation and operation during starting, this transition can be made smoothly and with a minimum of problems.

### **2. Preparation**

Before beginning the operation of a sputter ion pump, it is advisable to consider some system and safety issues. If these issues are taken into account, both personal and equipment convenience will be assured. First of all, in order to take maximum advantage of the pumping speed available from the sputter-ion pump, the conductance, or access for gas flow should be maximized. This means decreasing the length and increasing the diameter of the tubing connecting the sputter-ion pump to the system.

Second, cleanliness should be observed in handling and preparing both the system and the sputter-ion pump. Exposure to oils, water vapor or dust can significantly add to the gas load, both during starting and continued operation. Even fingerprints can be harmful in contributing to gas loads. Sputter-ion pumps do not deteriorate just by being stored at atmospheric pressure, if they are kept clean. Aluminum foil or a plastic cover on the inlet flange during storage will keep out dust, dirt and debris.

Finally, for personal safety, always establish a definite electrical grounding connection from the sputter-pump case to control unit ground. Sputter-ion pumps operate with high voltages and current levels which can be fatal if accidental contact is made. By assuring proper grounding of the pump, personal safety is greatly improved, and proper operation of control unit overload circuits is provided.

### **3. Control Unit/Power Supply**

Each sputter-ion pump requires a control unit of an appropriate voltage level, polarity and current capacity. These parameters are best determined by consulting the User Manual for the sputter-ion pump and/or the control unit. If the original documents are not available, the manufacturer’s catalog may have the information. In any case, you can call Duniway Stockroom, where a comprehensive listing of this information is maintained. (“Varian and Perkin Elmer Ion Pump Control Units, 1961-1992, 1992-1996.”)

Voltage is usually rated as “open circuit voltage”, that is the voltage with no current load on the control unit. Current is usually rated as “short circuit current”, that is the current drawn by the power supply when the output is shorted to ground.

The product of voltage and current at any point in the process gives the power going into the sputter-ion pump. This information is displayed as plot of power versus current. This plot has a power maximum near the middle range of the current capacity. This maximum is called the “power hill”, because as the pump current moves either up or down (the same as the pressure moving up or down) it must climb this “power hill”. Increasing power means increasing heat to be dissipated, which normally means an increasing gas load due to outgassing. As we will see

below (5. Starting), the heating that takes place due to power dissipation has an effect on the starting of the pump.

Sputter-ion pump current is proportional to pressure, especially in the pressure ranges below  $10^{-5}$  torr. This relationship is expressed by the equation:  $I/P = \text{constant}$ . Thus, at lower pressures, pump current can be used as an indicator of the pressure. An example of the relationship between sputter-ion pump current and pressure is shown attached as Figure 8.

#### **4. Roughing/Trapping**

Sputter-ion pumps operate by using a low pressure gas discharge called the Penning discharge. Through a combination of magnetic field and electric field, gas ions are formed and captured on active metal plates, such as titanium. The Penning discharge only operates at pressures below approximately  $10^{-3}$  torr, so the pressure in the pump and vacuum system must be reduced by other means to reach that pressure range.

A variety of rough vacuum pumps is available, including rotary mechanical pumps, turbomolecular pumps, and sorption pumps. Since the sputter-ion pump is inherently clean and typically used in clean, ultra-high vacuum applications, it is important to use a clean technique for rough pumping. Also, the roughing pump should have a valve to isolate it from the sputter-ion pump after the starting phase, since the sputter-ion pump can operate independently on a closed system. In addition to the gases contained in the volume of the system, the main gas load at the lower pressures is represented by the water vapor that is adsorbed on all the surfaces of the system.

It is a good idea to check the base pressure obtained by the roughing pump to assure that the pump is reaching a pressure adequately low for sputter-ion pump starting. A properly calibrated thermocouple gauge will do the job, and a pressure below 10 millitorr indicates adequate roughing pump performance. Lower pressure before starting will generally lead to quicker results.

The cleanest roughing pump technology is the sorption pump, which uses ultra-high surface area materials such as molecular sieve, which are chilled to liquid nitrogen temperatures. Water vapor, oxygen, nitrogen, argon and most organic vapors are pumped by sorption pumps, thus reducing the pressure to a few millitorr. For small systems a single stage sorption pump is sufficient to reach the starting pressure for sputter-ion pumps; for larger systems a sequenced, two stage sorption pump is recommended. Prior to using a sorption pump, it is important to remove the previously absorbed gases, particularly water vapor, by baking the pump.

Rotary mechanical pumps, which use oil-sealed vanes, can also be used for rough pumping; however, an effective trap must be provided between the mechanical pump and the sputter-ion pump. Either a liquid nitrogen trap or a molecular sieve trap can be used to keep the mechanical pump oil from migrating into the sputter-ion pumped system. In addition, the trap will help remove water vapor, the major gas load during the later stages of rough pumping. Mechanical pumps are not efficient at removing water vapor, since it just gets recycled through the oil on each rotation of the pump rotor.

Another good alternative for rough pumping is the turbomolecular pump. This pumping technology is clean and provides a better pumping speed and lower roughing pressure than other alternatives.

## 5. Starting

When the roughing pressure falls below 10 millitorr, the sputter-ion starting process can begin. To review the precautions, be sure that the pump is properly grounded, that the control unit voltage polarity and power rating are matched to the pump being started.

Verify that the control unit "Start-Protect" switch is set to the "Start" position, and that the "Meter Range" switch is set to "Voltage". Now turn on the "Power" switch. Immediately after turning on the power switch, observe the voltage reading on the meter. In the starting mode, the voltage should be in the 300-1000 volt range, and then gradually rise as the pump starts. (If the voltage reading is either at zero or at the open circuit rating of the control unit when the pump is turned on during starting, immediately turn the control unit off, because there is either an electrical short in the pump or an open circuit which must be found and corrected before proceeding.)

Next, turn the meter switch to the highest current scale and verify that the current is near the appropriate (near short circuit current) for the control unit. Return the meter range switch to the "Voltage" position to monitor the operation of the pump. When it appears that the roughing system has reached its base pressure, close the valve between the roughing system and the sputter-ion pump and observe the results on the "Voltage" scale of the control unit. If the voltage falls, indicating a rising current (rising pressure), reopen the roughing valve. If the voltage increases or remains the same, leave the roughing valve closed.

NOTE: with a sputter-ion pump, a modest rise in pressure is normal during the initial starting phase. This is caused by heating of the pump components by the dissipated power and normally precedes operation in the normal mode. Some heating during starting is beneficial because it causes out-gassing of components which will not have to take place during later stages of the system pump down. Excessive heating due to prolonged high pressure operation or a mismatched control unit can damage a pump. Operation in the start mode should always be monitored. The electrical discharge in a sputter-ion pump gives off a blue/purple glow due to the electron-gas ionization process taking place. At starting pressures, above  $10^{-4}$  torr, the discharge occurs throughout the pump; in some cases it can extend into the system itself. If the presence of this discharge in the system is a problem, a stainless steel, electrically grounded screen can be placed across the mouth of the pump. As the sputter-ion pump starts, the discharge confines itself to the area within the pump elements, and gradually becomes fainter as the pressure, and thus the rate of ionization, falls.

# 3 Operation/Protection

## A Introduction

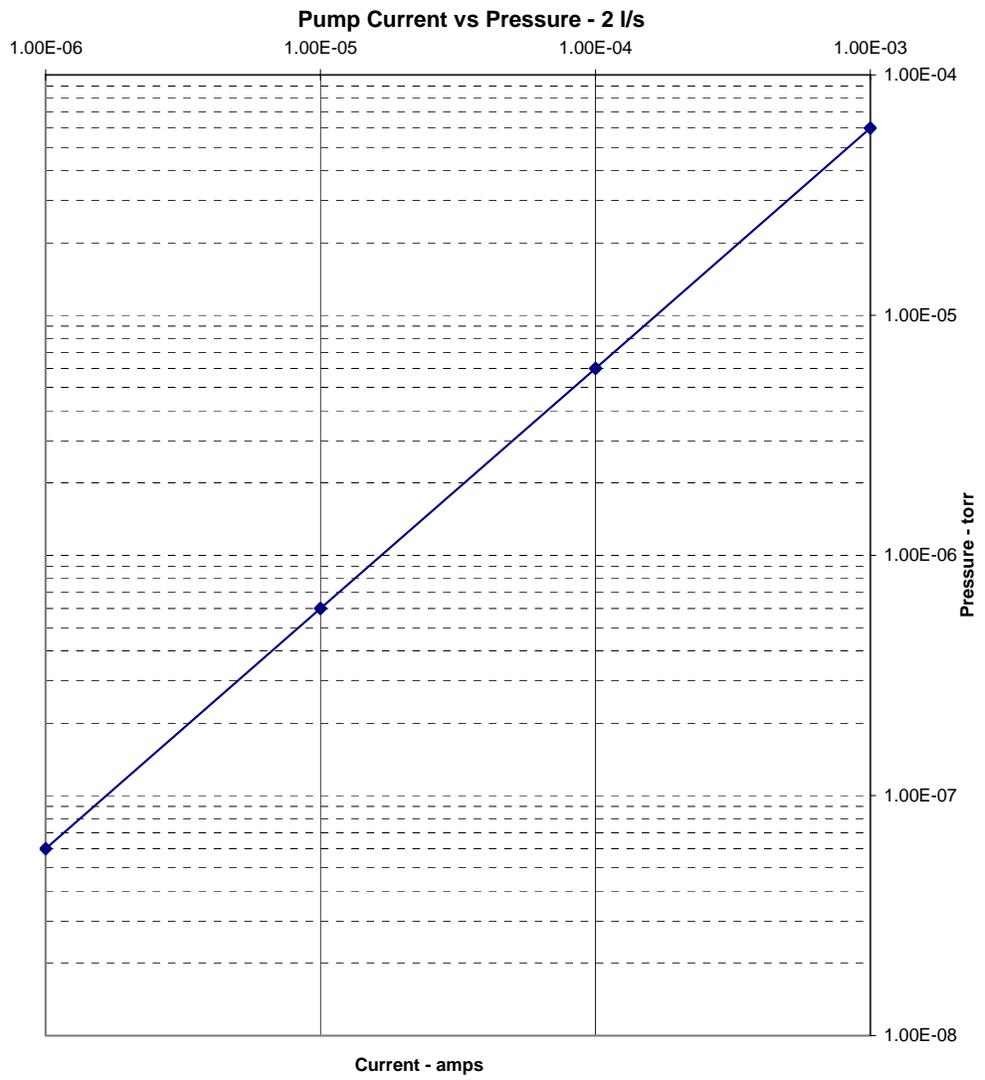
After the sputter-ion pump starts, as indicated by the voltage rising toward the open-circuit rating and current falling to below about 25% of the rated value on the control unit meter, normal operation can commence.

In normal operation, the roughing pump valve is closed and the “Start/Protect” switch on the control unit is placed in the “Protect” position. The pump is now protected against a pressure rise above approximately 0.5 millitorr while unattended. Should such a pressure rise occur due to a leak or other failure, the control unit will automatically turn off after a brief delay. This protects both the pump and control unit against excessive current and heat conditions.

During normal operation, pump current is proportional to pressure over a wide operating range. This is illustrated in the typical current vs. pressure curves shown below in Figure 9. By knowing the current and using the correct curve for that pump and control unit, the pressure can be calculated. In addition, most control units have a “Pressure” scale, which is a logarithmic scale from below  $10^{-9}$  torr to above  $10^{-4}$  torr. Also, a recorder and control signal, with a range from 0 to 100 mV, is normally available for monitoring the pump pressure.

## B Pressure Indication

As discussed above, sputter-ion pump current is proportional to pressure over the operating range. The graphs in Figure 9 below show typical plots of Ion Pump Current vs. Pressure for a 2 l/s pump. Caution should be used in using ion pump current to indicate pressure, especially at low pressures, due to potential leakage current, as discussed below in “Maintenance”.



**Figure 3: Sputter-Ion Pump Current vs. Pressure  
2 l/s appendage ion pump**

# 4 Technical Specifications

## A High Voltage Supply Input Rating

It is important to operate the pump with the proper control unit. Diode appendage ion pumps are rated to operate with a control unit that supplies +3,300 volts DC.

## B Vacuum Flange Connection

On pumps with flanges, the vacuum connection from the pump to the system is a ConFlat type flange. These pumps come sealed with a cover flange, a copper gasket and stainless steel screw/nut sets. Connection to the vacuum system requires a new copper gasket. Extra flanges, nuts, bolts, washers and gaskets are available from Duniway Stockroom Corp.

## C Grounding Requirements

Due to the hazardous nature of the high voltage used to operate this pump, it is important that proper grounding be present at all times during pump operation. Dual grounding means are provided: The first grounding means is through the high voltage connector outer cable shield and shell which are connected, via the “garter spring” on the pump high voltage feed through, to the pump body when installed. See Figure 5 above. The second grounding means is through a separate grounding cable which is connected to the case of the control unit and the grounding boss/lug on the pump case.

## D External Environmental Range

Operating temperature range: 32oF (0oC) to 100oF (38oC)

Maximum baking temperature, non operating, without magnet: 775oF (450oC)

Relative Humidity: 0% - 90% non-condensing

Elevation: -1000 ft (-300 meters) to +10,000 ft (+3000 meters) MSL

## E Vacuum Operation Range

Maximum Starting Pressure: 2 x 10<sup>-3</sup> torr (2 microns, 2 millitorr)

Continuous Operating Range: 10<sup>-4</sup> torr to below 10<sup>-11</sup> torr

## F Model Number Cross Reference Table - 0.2 l/s Appendage Pumps

Duniway Order #	Varian Equivalent	Element Type	Pump Speed
VA1-CU/A-AIR	913-0040	Diode	0.2 l/s
VA1-ST/A-AIR	913-0041	Diode	0.2 l/s
VA1-CU/A-VAC	913-0050	Diode	0.2 l/s
VA1-CU/L-AIR	913-0037	Diode	0.2 l/s
VA1-ST/L-AIR	913-0038	Diode	0.2 l/s
VA1-ST/L-VAC	913-0049	Diode	0.2 l/s
MAG-0042	913-0042	Alnico	

**G Model Number Cross Reference Table - 2.0 l/s Appendage Pumps**

Duniway Order #	Varian Equivalent	Element Type	Pump Speed
VA2-38CU-VAC	913-0035	Diode	2 l/s
VA2-75ST-AIR	913-0032	Diode	2 l/s
VA2-75ST-VAC	913-0045	Diode	2 l/s
VA2-MINI-VAC-B	913-5000	Diode	2 l/s
VA2-TEE-AIR	913-0046	Diode	2 l/s
MAG-0011	913-0011	Alnico	
MAG-0112	913-0112	SmCobalt	

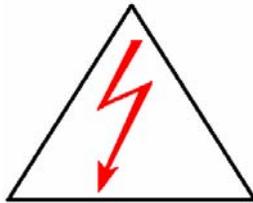
# 5 Maintenance

## A Leakage Current & Hi-Potting

After prolonged operation, which generates quantities of sputtered material inside the pump, it is possible that current leakage, not related to pump pressure, may develop in the pump. There are two types of leakage: “Resistive Leakage” and “Field Emission Leakage”. (In both cases, such leakage can be confirmed by removing the pump magnets, which should not substantially change the leakage current.)

Resistive Leakage is due to resistive coatings or short circuits of insulating elements in the pump. The presence of this leakage can be detected by using a simple ohm-meter or multimeter on the ohm or resistance scale. When resistive leakage occurs, pumping action is usually reduced or stopped, and the pump or must be replaced.

Field Emission Leakage is due to electron release from small points or flakes in the pump, at the high voltages inside the pump. This problem does not effect the pumping action of the pump, however it may be annoying if the pump current is used as an indication of the pressure in the system. In order to reduce or eliminate field emission leakage, it is possible to apply an over-voltage, a process known as “hi-potting”. Since field emission current grows exponentially with voltage, the application of higher than normal voltage can cause enough current to flow to melt the sharp points and reduce the leakage to an acceptable level. A Hi-Pot unit with voltages of 12-15 kV AC at a few milliamps is usually adequate to reduce the field emission leakage to an acceptable level. For more information on this procedure, call Duniway Stockroom Corporation.



NOTE: Extreme caution must be exercised when performing such an operation due to the hazardous nature of the voltages involved. Proper insulation and grounding must be supplied in order to avoid injury to personnel and damage to equipment.

## B Leak Checking

If prolonged operation, especially after baking of the system, does not result in appropriately low pressures, it is possible that there is a leak in the system. Some level of leak checking can be performed by observing the ion pump current while probing the exterior of the system with a probe gas such as helium. When the probe gas enters the system through a leak, it will cause a pump current fluctuation, related to the difference in leak rate for different diameter atoms and the difference in ionization potential of the probe gas in the ion pump discharge. More sensitivity may be obtained by using a strip chart recorder or computer display to record the pump current.

## C Magnet Checking

If the sputter ion pump does not seem to be operating with its normal pumping speed, it is possible that there may be a problem with magnet field strength or magnet installation.

The magnetic field should be between 1000-1500 gauss for most Sputter-Ion pumps. Higher magnetic fields give somewhat higher pumping speed, especially at low pressure.

#### **D Demounting the Pump**

If for any reason, it becomes necessary to remove the pump from the system, be sure to take the proper precautions for personnel and equipment safety. First of all, turn the control unit to the off condition. Then, remove the high voltage connector from the pump. At this point it is a good idea to remove the magnet from the pump to ease handling. Also, it is not a good idea to let the system up to atmospheric pressure by removing the sputter-ion pump, because any loose material around the gasket may be swept into the system. The system should be vented prior to the removal of the ion pump. On flanged pumps, loosen all the bolt/nut combinations slightly before completely removing any of the bolts.

#### **E Factory Maintenance**

Due to the size and construction of the appendage pumps, maintenance is not practical. A failed pump should be replaced with a new unit.

#### **F High Voltage Feedthrough**

The high voltage feedthrough is welded to the pump and is not serviceable. If the feedthrough is damaged or develops leakage current during transportation, installation or prolonged useThe entire pump must be replaced.



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