

# **Ion Pump Operation & Trouble Shooting Guide**

Provided as a Service by Duniway Stockroom Corp.  
Compiled by Sherman Rutherford 7/97

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# Ion Pump Operation & Trouble Shooting Guide

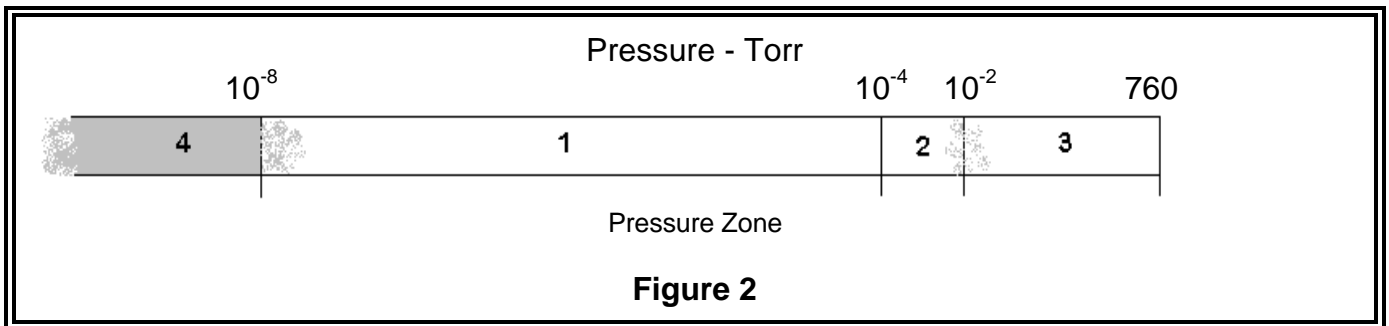
## Introduction:

Ion Pumps (Sputter-Ion Pumps, Getter-Ion Pumps, Penning Pumps) provide a clean, simple, low maintenance alternative for producing and maintaining high and ultra-high vacuum. Occasionally, questions or problems about performance may arise and this document is meant to help with resolving those issues. In solving problems with ion pumps, it may be helpful to review information on how they work and normal operating procedures. In that interest, this document includes appendices on principles of operation, starting and magnet circuits. Please review this information if you are not already familiar with ion pumps.

## Problems & Troubleshooting

**WARNING! Both line voltage used to power the control units and the voltages developed in these units and applied to the ion pumps are dangerous and exposure could be lethal. Proper grounding and high voltage connections are vitally important.**

**Problem:** Pump Won't Start (Starting is the process of going from roughing pressures, Zone 2 in the diagram in Figure 1, to the normal operating pressure, Zone 1)



Indication: No Pump Current: If the control unit shows that no current is being drawn by the ion pump which is being started, even though the meter shows the proper voltage, it could be caused by one of the following:

- Check that the polarity of the control unit high voltage is correct for the pump being used. Diodes, noble diodes and DI (Differential Ion) pumps require positive high voltage. Triodes and StarCell pumps require negative high voltage.

- Check to be sure that the magnets are installed, and that they are installed correctly. (See later section on magnet circuits).
- Check to be sure that the high voltage cable is properly connected to both the pump high voltage feedthrough and the control unit.
- Be sure that any safety features, such as ground protection relays, are operating properly.
- Verify that the pressure is within the Zone 1 or Zone 2 range - not either in Zone 3 where no discharge will occur or in Zone 4 where the pump current will be too low to indicate.
- As a last resort, check that the internal connections between the high voltage feedthrough and pumping elements are intact. Visual inspection and electrical continuity meter checking (keep things clean!) should be performed.

Indication: Excessive Heat During Starting. Some heating during starting of ion pumps is normal and in fact, beneficial in removing adsorbed gases. However, if during a prolonged starting process the pump becomes excessively hot, it could be due to the following:

- There could be a leak in the system, which is keeping the pressure from falling into Zone 1.
- The control unit could be over-powered for the pump being started. See Appendix II, below on Starting Ion Pumps for matching of pump models with control unit models.
- Excessive water vapor may have become adsorbed onto the pump elements and system surfaces during exposure to atmosphere, either at high humidity or over extended exposures. Bakeout of the pump and system is recommended.

Indication: The pump starts, but it won't pump down to expected base pressures.

- There could be a leak in the system, which is keeping the pressure from falling to acceptably low base pressures. The ion pump current can be used as a gross leak check; spraying helium or an acceptable liquid can give ion current fluctuations as gas composition changes or leaks become temporarily blocked.
- The system may be contaminated with a high vapor pressure material. The most common contaminate is water vapor, but other liquids, oils, fingerprints or high vapor pressure metals can clamp the pressure and stall a pump down. If contamination is indicated, thorough dis-assembly and cleaning of all interior surfaces with solvent and light abrasion is required.
- Are the magnets installed correctly and is the field strength up to specification for the pump?

**Problem:** Excessive Pump Current: The ion pump draws current substantially in excess of expected values based on the pressure in the system, or suddenly becomes higher than previously experienced.

Indication: The control unit current is at or approaching its rated short circuit current, and the voltage is substantially below its open circuit value.

- The pressure in the system has risen due to a leak or due to a process generating a high gas load.
- An electrical short has developed in the ion pump, due to a metallic object, such as a flake, becoming lodged in the pumping element or in the high voltage feedthrough. After turning off the control unit and removing the high voltage cable, use a Volt-Ohm-Meter to check the electrical resistance between the center conductor of the high voltage feedthrough and the metal jacket of the pump. The normal condition is open circuit, any indication of resistance is abnormal and may require rebuilding of the pump or elements.
- Electrical leakage due to conductive coatings has developed inside the pump; either due to heavy sputtering, generally at elevated temperatures or from other evaporative sources in the system. See previous point for diagnosis.
- Electrical leakage outside the pump, in the control unit, cables or connectors has developed. Check the control unit and cable independently of the ion pump to see if leakage current persists. Replace or repair faulty components.

**Problem:** Current not Proportional to Pressure. The system pressure is at the low levels expected, but the ion pump current remains at a higher value than expected from the pump specifications. There may be random spikes and variations

Indication: After considerable use, leakage current may develop in the ion pump. The current is unrelated to pressure in the system and persists even if the pump magnets are removed.

- No resistance can be measured even on the highest (Meg-ohm) scale of a multi-meter. This indicates field emission leakage current, which is due to buildup of sputtered material points or flakes. This effect can be removed or at least reduced by applying an over-voltage to the pump, for example, from a neon sign transformer at 15KVAC rated at a few milliamps. This process is called “hi-potting”, and other high voltage supplies can be used, as long as the current is limited to a few milliamps to avoid excessive heat.

**WARNING! Both line voltage used to power the control units and the voltages developed in these units and applied to the ion pumps are dangerous and exposure could be lethal.**

If the problem persists, a rebuild of the pump and elements is indicated.

- Resistance can be measured on the meg-ohm scale of a multimeter. This is probably due to buildup of conducting films on some of the high voltage stand-off insulators. The conductive films may come from sputtering within the pump, extended operation at high pressures (more than 0.1 micron) or deposits of conductive contaminants. If cleaning of the outside ceramic of the high voltage feedthrough does not solve the problem, a rebuild of the pump and elements is indicated.

**Problem:** Contamination of the pump by some high vapor pressure material.

Indication: System pressure remains above desired levels in spite of prolonged operation.

- Hydrocarbon contamination from oil or grease. This could be from an untrapped mechanical or diffusion pump, residual from machining operations, finger prints or organic sealing greases. For materials of this kind, a pump and system bakeout will help remove the materials. Presence of organic materials in the system may be detected as brownish or yellowish deposits on the glass portion of an ionization gauge or by sooty deposits in the ion pump.
- High vapor pressure materials, such as active metals (cesium, rubidium, etc.). These materials may come from an experiment or oven source as part of the process being performed in the vacuum chamber. Excess material may deposit in the cool parts of the vacuum system due to accidents or long term exposure. Such materials may be detected by a metallic sheen on interior of glass parts such as ionization gauges. Presence of such materials requires rebuilding of the ion pump and careful cleaning of the interior of the vacuum system.

**Problem:** Argon Instability

Indication: Diode pump displays regular, periodic pressure spikes, with the pressure gradually building up from the base pressure of the system to about  $10^{-4}$  torr, slowly falling into the upper  $10^{-5}$  torr range, then rapidly falling to the system base pressure.

The period of the fluctuation is roughly proportional to the base pressure between fluctuations; at  $10^{-8}$  torr base pressure the period can be days, at  $10^{-7}$  torr it can be hours, at  $10^{-6}$  torr it can be minutes.

- The pressure fluctuation is caused by re-emission of previously pumped argon (or other heavy noble gas), due to sputtering of the covered over areas. The instability disappears when the source of noble gas is eliminated, either by correcting an air leak or removing the source of noble gas. These fluctuations do not change the pumping mechanisms for chemically active gases, in fact, the additional fresh sputtered titanium actually increases the pumping speed, temporarily, for these gases.
- If sources of heavy noble gases cannot be eliminated from the system, the configuration of the pump elements must be changed to allow stable argon (heavy noble gas) pumping. See Appendix I for a more detailed discussion of pumping elements and pumping mechanisms.

## Handy Tips

**(Note: Always be sure to observe the safety precautions described in the ion pump and control unit operating manuals. Proper grounding of the ion pump and proper protection of the high voltage connections is mandatory. High voltages and currents developed are hazardous and can be fatal if safety precautions are not followed.)**

### **Procedure for opening an ion pump to atmospheric pressure:**

Water vapor from the atmosphere, adsorbed onto the surfaces of an ion pump and system, is normally the primary gas load encountered in starting the pump. Therefore, operators should take whatever measures to limit exposure to moisture laden air. This includes:

Keeping the pump sealed under vacuum until connection to the system.

Using dry nitrogen or dry air when letting the pump and system up to atmospheric pressure.

In general, limiting exposure of pump and system to the atmosphere, especially in regions where humidity is high and where temperature fluctuations may lead to condensation.

(Note: One layer of water molecules on the inside surface of a one meter cube, is approximately 3 torr-liters of gas, and, if completely desorbed into the volume would raise the pressure in the cube by  $3 \times 10^{-3}$  torr. In addition, surfaces in a vacuum system can adsorb many layers of water vapor before they saturate.)

### **Procedure for baking an ion pump:**

Since water vapor from the interior surfaces of the pump and system provide the majority of the gas load during pumpdown, acceleration of the desorption of the water layers will speed up the pumpdown. Ion pumps can normally be baked to 150°C while operating with the magnets on, and to 450°C with the magnets and cables removed. Heating tapes or special ovens can be used, taking precautions to avoid hot spots which might damage the system.

During starting of an ion pump, the power dissipated by the pumping elements at higher pressures (above  $10^{-5}$  torr) causes heating of the elements and surrounding pump structure. If the control unit is properly matched to the pump, this heating will not be excessive; in fact, it can provide beneficial removal of adsorbed water vapor, which will lead to faster pumpdown subsequently. (See Appendix II for more information on starting ion pumps and matching control units to ion pumps.)

If the pump has been exposed to large amounts of water vapor, starting can take extended time. Heating due to power dissipation keeps the operation of the pump in the high power zone of the control unit, leading to water desorption, more heat, etc. Manually shutting the pump control unit off-and-on to reduce the duty cycle and heat dissipation, while still operating the roughing pump, can speed up the starting of the ion pump. (See Appendix II for more information on starting ion pumps and matching control units to ion pumps.)

### Procedure for 'Hi-Potting' an Ion Pump

After extended operation of an ion pump, where sputtered material deposits may form flakes with sharp points, field emission current leakage may occur. Field emission current results from electrons being extracted from sharp points under high voltages. The resulting high voltage gradients are high enough to draw electrons directly from the metal points. The resulting current has a threshold and is exponentially related to the applied voltage above the threshold. While very useful in some applications, this current is annoying in ion pumps because it can mask the true ion current for purposes of indicating the pressure in a pump.

Reduction of field emission leakage current is accomplished by a process called 'hi-potting'. Taking advantage of the exponentially increasing current with applied voltage, the sharp points can be burned off by applying an over voltage to the point where current flow causes melting of the tip. Hi-potting control units, with variable high voltage and over-current protection are commercially available. Turning the control up to 15 -20 KV usually does the job. Use of a neon sign transformer, with 15 KVAC and a few milliamps of short circuit current has also been effective.

**WARNING! Both line voltage used to power the control units and the voltages developed in these units and applied to the ion pumps are dangerous and exposure could be lethal.**

If hi-potting does not reduce leakage current to appropriately low values, then the pump probably needs rebuilding due to conductive coating on insulator surfaces.

Some times, offending particles can be removed from critical positions by vibration. For example, light tapping of the pump envelope with a soft-faced hammer or screw-driver handle can cause the particles to break loose and move to less critical positions. Use **caution** in the force used in this process; stay away from the cables and high-voltage feedthroughs.

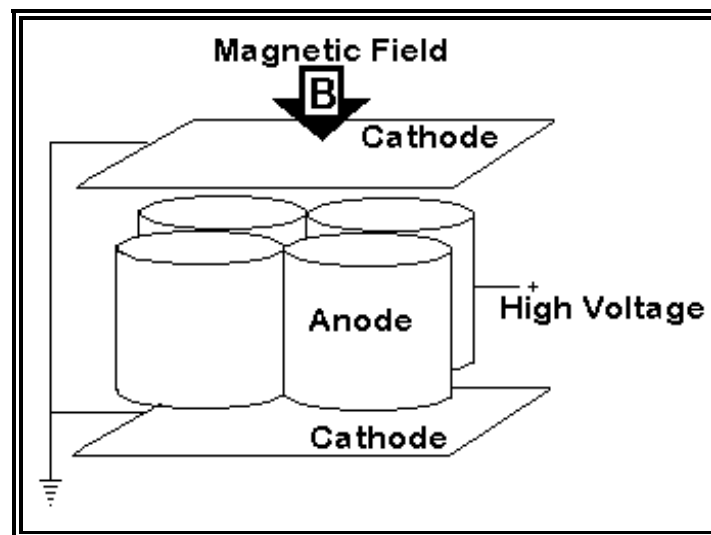
## Appendix I: How an Ion Pump Works:

Ion pumps work by using an electrical, ionizing discharge which is maintained under vacuum conditions, and chemically active metals, such as titanium. The discharge is called a *Penning Discharge*, after its discoverer, F.M. Penning in 1937.

Ion pumps require a correct combination of geometry, materials, high voltage, magnetic field and pressure range to operate.

**WARNING! Both line voltage used in control units and the voltages developed in this unit and applied to the ion pumps are dangerous and exposure could be lethal.**

Geometry and Material: Typical ion pumps consist of an anode structure (an array of hollow cylindrical cells made of stainless steel tubing), suspended between a set of two cathode plates (made of titanium). See Figure 1 below. The whole array is mounted in a vacuum envelope, with good conductance access to the volume being pumped.



**Figure 1 - Diode, DI, and Noble Diode Ion Pumps**

Voltage: A positive high voltage is established between the anode and the cathode plates. The voltage typically is in the range of 3000 to 7000 volts DC. (see “Types of Pumps” below for variations.) High voltage feedthroughs and stand-off insulators are used to isolate the anode from the cathodes and the vacuum envelope.

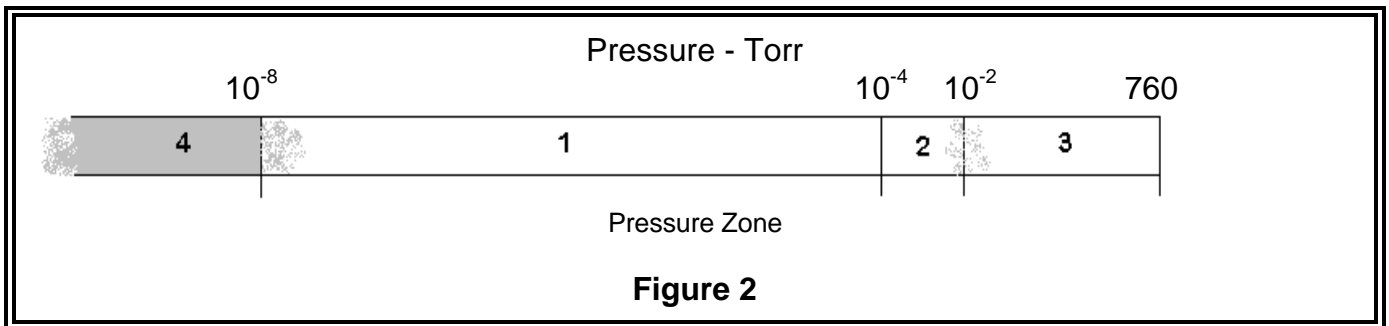
**Magnetic Field:** A magnetic field is required, aligned with the axis of the anode cells. The field is generally between 1000 and 2000 gauss; it should be parallel to the axis of the anode cells and should be uniform across the array. See Appendix III for more information about magnets and their circuits.

**Pressure/Vacuum Range:** Ion pumps are designed to operate continuously in the range between  $10^{-4}$  torr and to  $10^{-8}$  torr and below. (Zone 1 in Figure 2 below). In Zone 1, the electrical discharge is strong, efficient and confined to the anode cells. In this region, a cloud of electrons circulates inside the anode cells, constrained by the combination of electrical and magnetic fields. The circulating electrons collide with gas molecule to form positive ions and secondary electrons. The secondary electrons help maintain the intensity of the circulating electron cloud. The positive gas ions, are attracted to the cathode plate, and because they have a much greater mass to charge ratio than the electrons, their path is much less curved, and they collide with the titanium cathode.

At pressures between  $10^{-4}$  and  $10^{-2}$  torr (Zone 2), the pump operates, but in a less efficient, unconfined discharge mode. In most cases, roughing pumps are used to lower the pressure into the Zone 2 range, then the ion pumps is “started”.

At pressures from atmosphere (760 torr) down to several torr, no discharge will occur; depending on the geometry. The unconfined glow discharge starts at the lower end of Zone 3 and extends through Zone 2.

In Zone 4, the ultra-high vacuum range below  $10^{-8}$  torr, depending on the strength of the magnetic field and diameter of the anode cells, the discharge intensity, and therefore pumping speed can decline. This is because the discharge goes into a lower intensity mode due to the loss of electrons from the discharge. The product (BxD) of magnetic field strength, B and cell diameter, D determines the transition point from Zone 1 to Zone 4. High values of BxD can push this transition point to below  $10^{-11}$  torr.



Zone 1:	$10^{-4}$ to $10^{-8}$ torr	Normal Operating Range
Zone 2:	$10^{-2}$ to $10^{-4}$ torr	Starting Range
Zone 3:	~1 to 760 torr	Non-Operating Range
Zone 4:	$10^{-8}$ torr & below	UHV Range

## Pumping Mechanisms for Different Gas Species

The combination of ionization, ion bombardment, sputtering and general collision of gas molecules with the pump walls leads to pumping by a variety of mechanisms.

Chemically Active Gases: Most of the pumping in ion pumps takes place by direct chemical combination between the active gas ions/molecules as they strike the chemically active titanium surfaces. Oxygen and nitrogen form very stable compounds with titanium, so once they are pumped they are permanently removed from the vacuum system.

Small Atoms: Small diameter atoms, such as hydrogen and helium, are pumped by ionization, burial and subsequent diffusion into the cathodes. Hydrogen, especially, since titanium has a very high affinity for dissolving hydrogen, can be pumped in very large quantities. Unfortunately, under heating, it can also come out of solution and be re-emitted into the system. Buried and diffused helium also can be re-emitted by heating.

Heavy Noble Gases: Since the noble gases are chemically neutral, they must be pumped by burial and covering over by subsequently sputtered material. If the noble gas ion is initially buried in an area of heavy subsequent sputtering, it can be re-emitted as it is uncovered. This burial and re-emission, in some cases, can lead to a periodic pressure fluctuation called argon instability. Since the atmosphere has about 1% argon as a constituent, the desire for stable pumping of argon has led to alternate configurations in which the areas of net build-up of sputtered material are enhanced.

Complex Molecules: Molecules such as water, methane, carbon dioxide, carbon monoxide, ammonia and light hydrocarbons are dissociated in the discharge and their chemical components are pumped by their normal mechanisms.

## Types of Pumps

Diode: The earliest and most common type of pump is called the “Diode” configuration and it is shown in Figure 1. Both cathode plates are made of titanium and the anode is operated at positive high voltage. This configuration is simplest, least expensive and most reliable for normal operation against outgassing loads and at low pressures.

Differential (DI) or Noble Diode: However, the need to operate against steady air leaks and with artificial loads of heavy noble gases, especially argon, lead to new configurations. In one such variation, the pump is the same as shown in Figure 1, except that only one cathode is made of titanium, while the other is made of a substantially heavier metal, such as tantalum. The slower sputtering rate of the heavier metal shifts the balance of areas where there is a net buildup of buried atoms and sputtered material. This shift leads to higher pumping speeds and stable pumping for noble gases.

Triode or StarCell: Another variation for stable noble gas pumping is the triode. In this configuration, the anode is maintained at ground potential while the cathodes are operated at a negative high voltage. The cathodes are constructed of strips of titanium, providing grazing incidence sputtering. See Figure 3. In the StarCell variation, the anode-cathode voltage relationship is the same as in the triode, but the cathode has open areas with star-shaped slats arranged radially around the opening. In both these configurations, the cathode geometry provides enhanced areas where there is a net buildup of buried atoms and sputtered material. This shift leads to higher pumping speeds and stable pumping for noble gases.

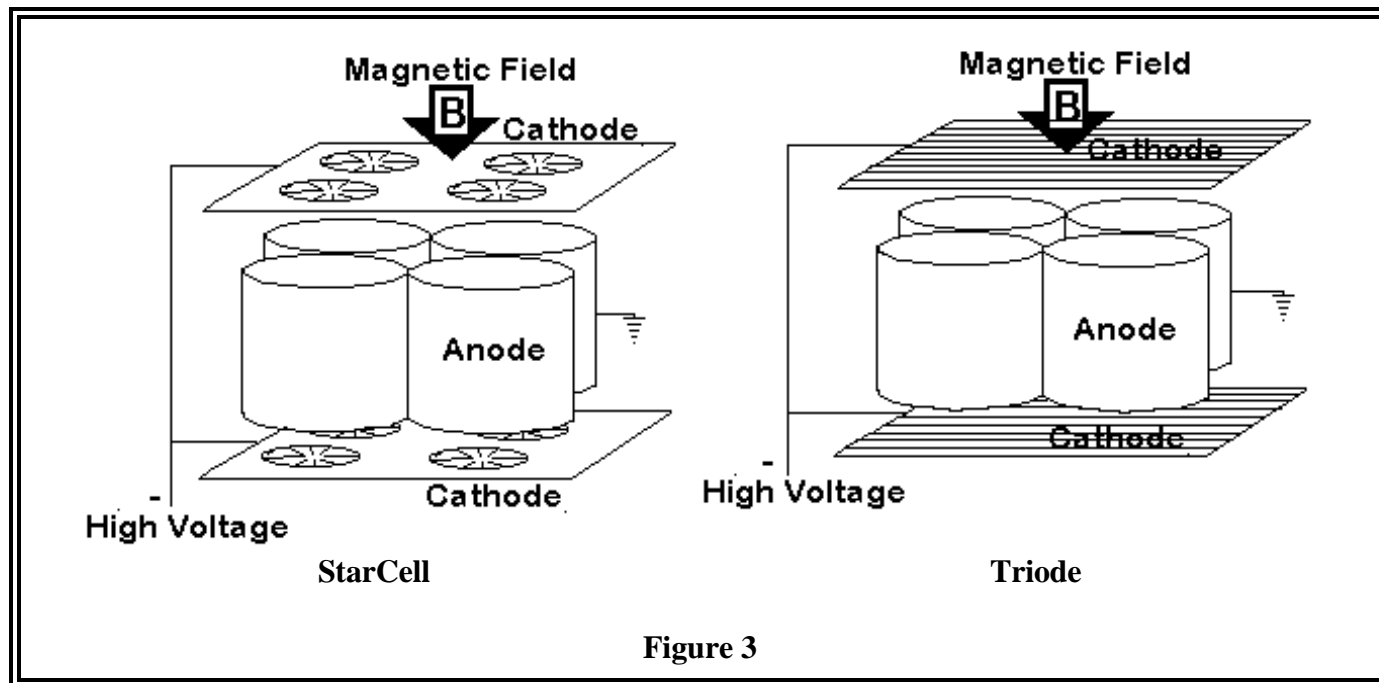


Figure 3

## Appendix II: Starting Sputter-Ion Pumps

### 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. Pre-Start Checking

Ion pumps are normally delivered under vacuum. They have been baked and processed, then sealed with a copper pinch-off. Before opening the pump, it is a good idea to check the condition of the vacuum in the pump. Visually check the pinch-off and high voltage feedthrough for integrity, attach a ground connection to the pump and attach the high voltage connector to an appropriate control unit. Put the meter scale to ‘Pressure’ or the lowest current range. Turn on the control unit. A brief spike of current should occur, due to pressure build-up in the pump, then the current should fall into the microamp range. In many cases the current will fall below the level readable on the current meter, and in every case should fall rapidly to below 2 microamps.

### 3. 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.

#### 4. 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 may call Duniway Stockroom, where a comprehensive listing of this information is maintained. An example of the information available "Varian and Perkin Elmer Ion Pump Control Units, 1961-1992, 1992-1996" is attached.

In general, the larger the pump rating in liters per second, the higher the required current capacity. Also, triode configurations (triode or StarCell) require negative voltage polarity while diode configurations (diode, noble diode, DI) require positive voltage polarity.

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.

An example of voltage and power versus current for a typical sputter-ion pump control unit, a Duniway Stockroom Corporation IPC-0066, is shown in the attached Figure 1.

In the plot in Figure 1, the voltage is represented on the vertical axis by the bars, the power is represented on the vertical axis by the line plot and the current is represented on the horizontal axis. The voltage rating of the power supply is shown by the maximum voltage plot at the upper left of the graph, or approximately 7,200 volts; the current rating of the power supply is shown by the point in the lower right of the plot where the power curve intercepts the lower axis, or .58 amps (580 ma); and the power rating is shown by the top of the power curve, or 1200 watts.

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 (6. 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 2; in this case the pumps are Varian 8,20, 30 and 60 liter per second diodes. The slope of the upper I/P curve shown (for the 60 liter per second pump) is 1000 amps per torr. (Calculated by choosing a typical point on the curve, say 10 milliamps at  $1 \times 10^{-5}$  torr, and dividing the current at that point by the pressure at that point).

## 5. 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 efficient 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.

## 6. 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.

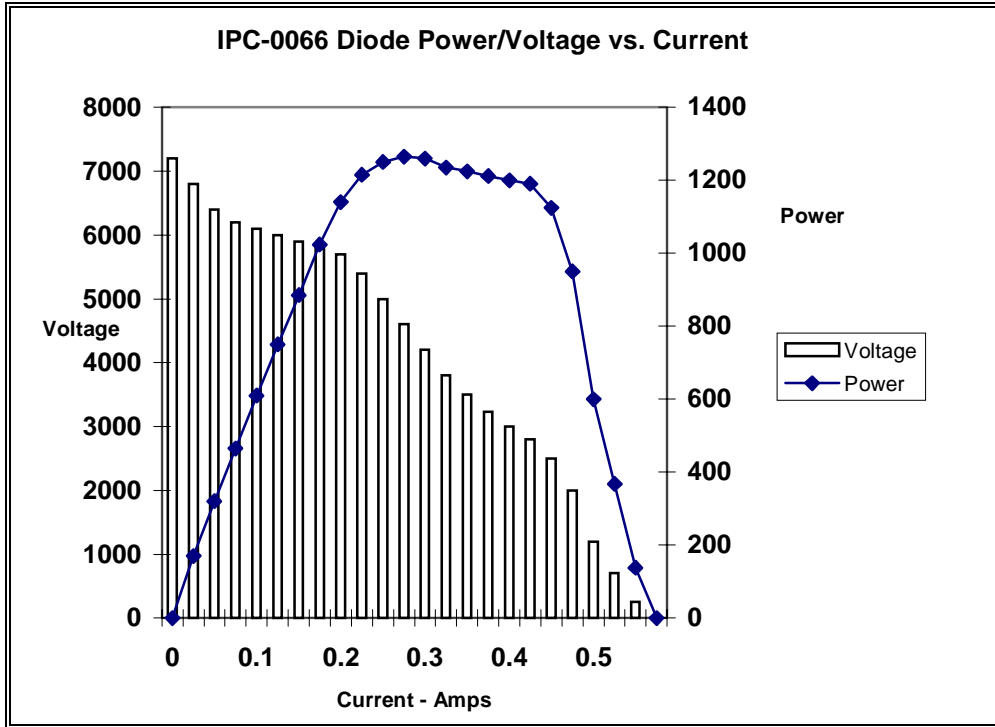
The electrical discharge in a sputter-ion pump gives off a blue/purple glow due to the electron-gas ionization process taking place. At starting pressures, above  $10^{-4}$  torr, the discharge occurs throughout the pump; in some cases it can extend into the system itself. If the presence of this discharge 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.

## 7. Operation/Protection

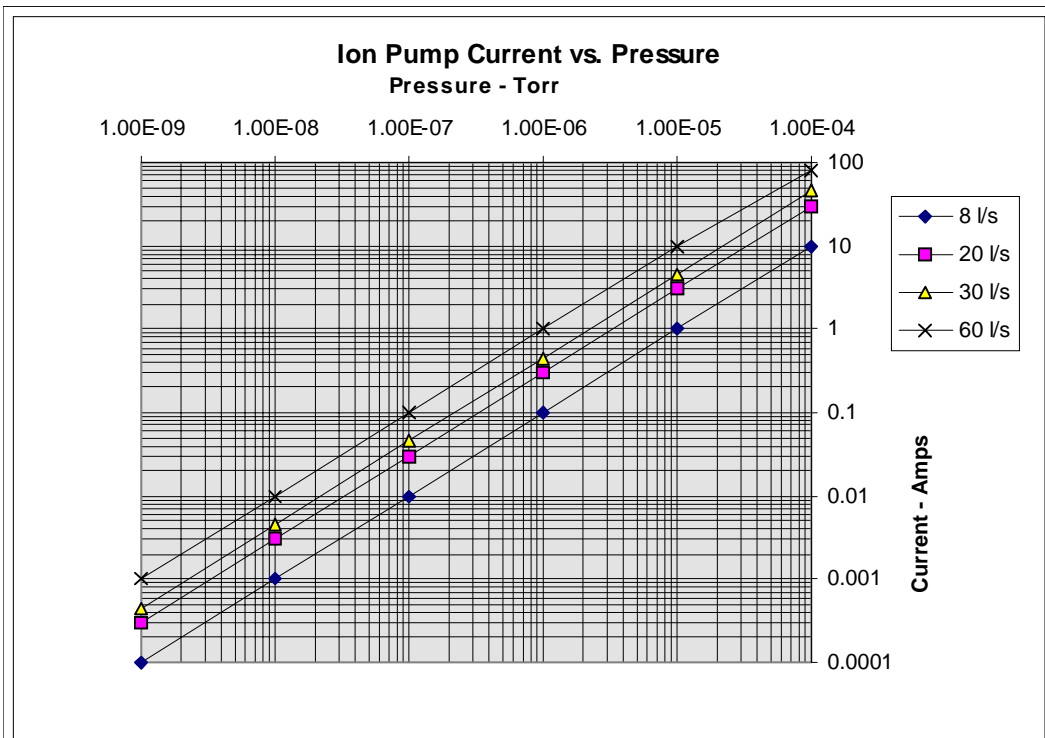
After the sputter-ion pump starts, as indicated by the voltage rising toward the open-circuit rating and current falling to below about 25% of the rated value on the control unit meter, normal operation can commence.

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 mTorr 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 (Varian 8-60 l/s diodes) current vs. pressure curve shown below in Figure 2. 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.



**Figure 1 - Typical Sputter-Ion Control Unit Voltage and Power vs. Current**



**Figure 2 - Typical Sputter-Ion Pump Current vs. Pressure (Varian 8-60 liter per second diodes)**

**DUNIWAY STOCKROOM CORP. - 1305 Space Park Way - Mountain View, CA 94043 - 800-446-8811**

**'Perkin Elmer/Ultek Ion Pump Control Units 1961-1992**

Item #	Pump Speed liters/sec	Model Number	Output Volts*	Output MA	H.V. Cable	Input Volts	Input Hz	Mounting Height	Mounting Width	Ship** Weight	Orig. Year	Description
1	Appendage	60-013	2900	3	yes	115	60	cabinet		13	1961	linear meter
2	Appendage	222-0330	4750	10	no	115	60	cabinet		15	1972	
3	Appendage	222-0370	4750	10	no	115	60	5"	19"	15	1972	
4	Appendage	222-0380	4750	10	yes	220	50	5"	19"	15	1972	
5	Appendage	222-0350	4750	10	yes	220	50	cabinet		15	1972	
6	Ionpak 200	222-0200	5500	2.5	yes	120	60/50	small box		5	1984	low power high power low power high power
7	5-9	60-056	3200	150	yes	115	60/50	cabinet		37	1961	
8	5-11-20-25	60-062	4750	150	yes	115	60	5.25"	19"	37	1964	
9	5-11-20-25	222-0400	4750	150	yes	115	60	5.25"	19"	37	1968	
10	5-11-20-25	222-0451	4750	150	yes	220	50	5.25"	19"	37	1968	
11	5-11-20-25	222-0410	4750	150	yes	115	60	5.25"	19"	37	1972	
12	5-11-20-25	222-0460	4750	150	yes	220	50	5.25"	19"	37	1972	
13	1-5-11	222-0360	+/- 5500	60	yes	117/208/230	60	5.25"		38	1977	
14	20-25-60-80	222-0360	+/- 5500	100	yes	117/208/230	60	5.25"		38	1977	
15	1-5-11	222-0365	+/- 5500	60	yes	100/200/220	50	5.25"		38	1977	
16	20-80	222-0365	+/- 5500	100	yes	100/200/220	50	5.25"		38	1977	
17	40	60-103	3200	350	yes	115	60	cabinet		80	1961	
18	50	60-104	4750	350	yes	115	60	8.75"	19"	70	1966	
19	50	60-105	4750	350	yes	115	60	8.75"	19"	70	1967	
20	50	222-0510	4750	350	yes	115	60	8.75"	19"	70	1972	
21	50	222-0560	4750	350	yes	200	50	8.75"	19"	70	1972	
22	60-150	222-0520	5500	350	yes	115	60	8.75"	19"	60	1974	
23	80-220	222-0530	+/- 5500	250	yes	115/208/230	60	6.5"	19"	70	1977	
24	80-220	222-0580	+/- 5500	250	yes	200/220	50	6.5"	19"	70	1977	
25	25-270	Digital 500	+/- 5500	220	yes	110/220	6050	5.25"	19"	49	1982	microprocessor
26	Boostivac	60-650	4750	350	yes	115	60	10"	19"	125	1963	6.5 volts - 50 amps
27	Boostivac	60-655	4750	350	yes	115	60	10"	19"	125	1964	6.5 volts - 50 amps
28	Boostivac	224-0620	4750	350	yes	115	60	10"	19"	125	1974	8.0 volts - 55 amps
29	Boostivac	224-0650	4750	350	yes	208/230	50	10"	19"	125	1974	8.0 volts - 55 amps
30	Boostivac	224-0630	+/- 5500	250	no	117	60	7"	19"	125	1977	8.0 volts - 62 amps
31	Boostivac	224-0635	+/- 5500	250	no	220	50	7"	19"	125	1977	8.0 volts - 62 amps
32	90-450	60-153	3200	1000	no	110	60	cabinet		140	1961	with meter relay
33	100-1200	60-154	4750	1000	no	208/230	60	8.75"	19"	148	1963	
34	100-1200	60-154-01	4750	1000	no	208/230	60	8.75"	19"	148	1964	
35	100-1200	60-160	4750	1000	no	208/230	60	8.75"	19"	130	1967	
36	100-1200	60-160-01	4750	1000	no	208/230	60	8.75"	19"	130	1967	with meter relay
37	100-600	222-0600	4750	1000	no	208/230	60	8.75"	19"	131	1972	with meter relay
38	100-600	222-0650	4750	1000	no	208/230	50	8.75"	19"	131	1972	
39	120-500	222-0630	+/- 5500	720	no	208/230	60	6.5"	19"	130	1977	
40	120-500	222-0680	+/- 7000	600	no	200/230	50	6.5"	19"	130	1977	
			+/- 5500	720	no	200/230	50	6.5"	19"	130	1977	
			+/- 7000	600	no		50					

\*Output Volts - Positive unless labelled otherwise \*\*Ship Weight in Pounds

H.V. Cable - Yes means included, hardwired in place; No means not included, demountable, order separately.

PE/Ultek Ion Pumps can be operated on Varian Ion Pump Control Units.

Call for information on operating multiple ion pumps from a single control unit.

**Call Duniway Stockroom for help in BUYING, SELLING & REPAIRING:  
Ion Pumps and Control Units from all Manufacturers**

**DUNIWAY STOCKROOM CORP. - 1305 Space Park Way - Mountain View, CA 94043 - 800-446-8811**

**Varian Ion Pump Control Units 1961-1992**

Item #	Pump Speed liters/sec	Model Number	Output Volts*	Output MA	H.V. Cable	Input Volts	Input Hz	Mounting Height	Mounting Width	Ship** Weight	Orig. Year	Description
1	Appendage	921-0006	3200	40	yes	115/230	60	cabinet		20	1961	Multiple Pump
2	Appendage	921-0015	3200	40	no	115/230	60/50	cabinet		20	1963	
3	Appendage	921-0014	3200	40+40	no	115/230	60/50	7"	19"	50	1963	
4	8-May	921-0011	3200	150	yes	115/230	60/50	7"	19"	52	1961	
5	Leak Det.	975-0000	3200	150	yes	115/230	60	10 1/2"	19"	60	1962	
6	15	921-0013	7200	70	yes	115/230	60/50	10 1/2"	19"	53	1963	
7	40-50	921-0012	3750	425	yes	115/230	60	10 1/2"	19"	65	1960	
8	75-80	921-0007	7200	190	yes	115/230	60	10 1/2"	19"	97	1960	
9	75-80	921-0027	7200	190	yes	115/230	50	10 1/2"	19"	97	1960	
10	140	921-0004	7200	235	yes	115/230	60	10 1/2"	19"	97	1960	
11	140	921-0024	7200	235	yes	115/230	50	10 1/2"	19"	97	1960	
12	280	921-0008	3200	900	yes	115/230	60	10 1/2"	19"	112	1960	
13	280	921-0028	3200	900	yes	115/230	50	10 1/2"	19"	112	1960	
14	400-500	921-0005	7200	750	yes	208/230	60	10 1/2"	19"	135	1961	
15	400-500	921-0025	7200	750	yes	208/230	50	10 1/2"	19"	135	1961	
16	11(Hi-Q)	921-0018	7200	750	yes	208/230	60	10 1/2"	19"	135	1961	
17	1000	921-0000	7200	1900	yes	230/280	60			525	1961	
18	140	921-0034	7200	300	yes	115/230	60/50	10 1/2"	19"	90	1966	
19	270	921-0036	7200	600	yes	115/230	60	10 1/2"	19"	100	1966	
20	270	921-0035	7200	600	yes	115/230	50	10 1/2"	19"	100	1966	
21	500	921-0038	7200	1250	yes	208/230	60	10 1/2"	19"	125	1966	
22	500	921-0037	7200	1250	yes	208/230	50	10 1/2"	19"	125	1966	
23	1000	921-0040	7200	1800	yes	208/230	60	10 1/2"	19"	160	1966	
24	1000	921-0039	7200	1800	yes	208/230	50	10 1/2"	19"	160	1966	
25	110	921-0041	-5200	400	yes	115/208/230	60	10 1/2"	19"	90	1966	
26	110	921-0041	-5200	480	yes	115/208/230	50	10 1/2"	19"	90	1966	
27	220	921-0043	-5200	800	yes	115/208/230	60	10 1/2"	19"	100	1966	
28	220	921-0042	-5200	800	yes	230	50	10 1/2"	19"	100	1966	
29	400	921-0045	-5200	1600	yes	208/230	60	10 1/2"	19"	125	1966	
30	400	921-0044	-5200	1600	yes	208/230	50	10 1/2"	19"	125	1966	
31	8 20,30 60	921-0062	3300 -5200 3300 -5200	120 200 100 167	no no no no	120/240 120/240 120/240 120/240	60 60 50 50	7"	8.31"	40	1970	
32	110, 140 220, 270 400, 500	921-0066	7500 -5200 7500 -5200	465 670 560 800	no no no no	208/240 208/240 208/240 208/240	60 60 50 50	7"	19"	80	1970	

\*Output Volts - Positive unless labelled otherwise \*\*Ship Weight in Pounds  
H.V. Cable - Yes means included, hardwired in place; No means not included, demountable, order separately.  
Varian Ion Pumps can be operated on PE/Ultek Control Units.  
Call for information on operating multiple ion pumps from a single control unit.

**Call Duniway Stockroom for help in BUYING, SELLING & REPAIRING:  
Ion Pumps and Control Units from all Manufacturers**

**DUNIWAY STOCKROOM CORP.** 1305 Space Park Way, Mountain View, CA 94043 **800-446-8811**

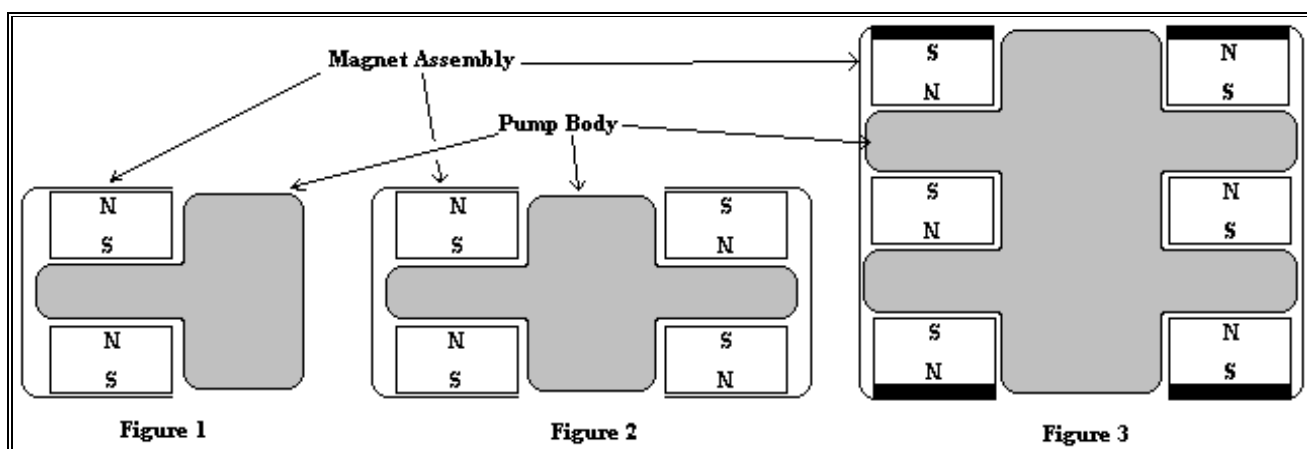
**Addendum: Ion Pump Control Units 1992-1997** (rev. 7/97)

Speed l/s	Model Number	Notes	Output		H.V. Cable	Input		Mounting (in.)		Weight #	Orig. Year	1996 Status
			Volts	Ma.		Volts	Hz.	Height	Width			
<b>VARIAN</b>												
2,8	921-2001	Vaclon Pump Control	3.5kv	1.6	no	115/220	50/60	3.8	3.8	6	1988	current
30,45,60	929-0080	Starcell	-7kv	200	no	120	60			48	1986	obsolete
20	929-0081	Starcell	-7kv	90	no	120	60			48	1986	obsolete
30-60	929-0170	Starcell	-7kv	170		220/240	50	7	8.3	64	1988	obsolete
20	929-0171	Starcell	-7kv	80		220/240	50	7	8.3	64	1988	obsolete
120-400	929-0172	Starcell	-7kv	300		22/240	50	7	19	88	1988	obsolete
30-60	929-0180	Starcell	-7kv	200		100/120	60	7	8.3	64	1988	obsolete
20	929-0181	Starcell	-7kv	95		100/120	60	7	8.3	64	1988	obsolete
120-400	929-0182	Starcell	-7kv	240		208	60	7	19	88	1988	obsolete
8-400	929-8000	µ8000- w. displ	+/- 3 to 7.5kv	800	no	110 & 220	50/60	7	8.3	28	1991	obsolete
8-400	929-8100	µ8000- no displ	+/- 3 to 7.5kv	800	no	110 & 220	50/60	7	8.3	28	1991	obsolete
2,8	929-0190	MiniVac	+/- 5kv	15	no	120	47-63	4.2	5.1	5	1995	current
all	929-0191	MiniVac	+/- 5kv	15	no	120	47-63	4.2	5.1	5	1995	current
all	929-0196	MiniVac	+/- 5kv	15	no	24	47-63	4.2	5.1	5	1995	current
2, 8	929-0197	MiniVac	+/- 5kv	15	no	24	47-63	4.2	5.1	5	1995	current
all	929-0290	MiniVac	+/- 5kv	15	no	220	47-63	4.2	5.1	5	1995	current
2,8	929-0291	MiniVac	+/- 5kv	15	no	220	47-63	4.2	5.1	5	1995	current
Base Unit	929-400X	Multivac Base	na	na	no	180-265	47-63	7	8.3	8	1995	obsolete
Base Unit	929-401X	Multivac Base	na	na	no	90-130	47-63	7	8.3	8	1995	obsolete
20-75	929-40X5	HV Cards	+/- 3, 5, 7kv	250	no	na	na	na	na	7	1995	obsolete
20-500	929-40X0	HV Cards	+/-1 to 7kv	10-400	no	na	na	na	na	7	1995	obsolete
20-60	929-5000	MidiVac X1 Neg	neg 3, 5, 7kv	100	no	90-130	47-63	7	8.3	10	1997	current
20-60	929-5001	MidiVac X1 Pos	pos 3, 5, 7kv	100	no	90-130	47-63	7	8.3	10	1997	current
20-60	929-5002	MidiVac X1 Neg	neg 3, 5, 7kv	100	no	180-265	47-63	7	8.3	10	1997	current
20-60	929-5003	MidiVac X1 Pos	pos 3, 5, 7kv	100	no	180-265	47-63	7	8.3	10	1997	current
20-60	929-5004	MidiVac X2 Neg	X2 neg 3, 5, 7kv	100	no	90-130	47-63	7	8.3	10	1997	current
20-60	929-5005	MidiVac X2 Pos	X2 pos 3, 5, 7kv	100	no	90-130	47-63	7	8.3	10	1997	current
20-60	929-5006	MidiVac X2 Neg	X2 neg 3, 5, 7kv	100	no	180-265	47-63	7	8.3	10	1997	current
20-60	929-5007	MidiVac X2 Pos	X2 pos 3, 5, 7kv	100	no	180-265	47-63	7	8.3	10	1997	current
20-500	929-6000	Multivac X1 Neg	neg 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	15	1997	current
20-500	929-6001	Multivac X2 Neg	X2 neg 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	22	1997	current
20-500	929-6002	Multivac X1 Neg Dig	neg 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	15	1997	current
20-500	929-6003	Multivac X2 Neg Dig	X2 neg 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	22	1997	current
20-500	929-6004	Multivac X1 Pos	pos 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	15	1997	current
20-500	929-6005	Multivac X2 Pos	X2 pos 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	22	1997	current
20-500	929-6006	Multivac X1 Pos Dig	pos 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	15	1997	current
20-500	929-6007	Multivac X2 Pos Dig	X2 pos 3, 5, 7kv	10-400	no	90-130	47-63	5.75	7.9	22	1997	current
20-500	929-6008	Multivac X1 Neg	neg 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	15	1997	current
20-500	929-6009	Multivac X2 Neg	X2 neg 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	22	1997	current
20-500	929-6010	Multivac X1 Neg Dig	neg 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	15	1997	current
20-500	929-6011	Multivac X2 Neg Dig	X2 neg 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	22	1997	current
20-500	929-6012	Multivac X1 Pos	pos 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	15	1997	current
20-500	929-6013	Multivac X2 Pos	X2 pos 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	22	1997	current
20-500	929-6014	Multivac X1 Pos Dig	pos 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	15	1997	current
20-500	929-6015	Multivac X2 Pos Dig	X2 pos 3, 5, 7kv	10-400	no	180-265	47-63	5.75	7.9	22	1997	current
<b>PERKIN ELMER</b>												
2-80	2220240	IONPAK	plus 5.6KV	8.6	direct	110/230	50/60	3.1	7.2	10	1984	current
2-80	2220242	IONPAK	plus 5.6KV	8.6	yes	110/230	50/60	3.1	7.2	10	1984	current
2-80	2220245	IONPAK	minus 5.6KV	8.6	yes	110/230	50/60	3.1	7.2	10	1984	current
2-80	2220272	DIGI-PAK	plus 5.6KV	8.6	no	110/230	50/60	3.25	6	10	1984	current
2-80	2220275	DIGI-PAK	minus 5.6KV	8.6	no	110/230	50/60	3.25	6	10	1984	current
25-270	2220400	DIGITEL	+/- 5.5kv	250	no	110/230	48-62	5.75	19	44	1982	obsolete
120-700	2221500	DIGITEL	+/- 5.5kv/7kv	750	no	230	48-62	7	19	105	1982	obsolete
8-80	635941	DIGITEL-MPC	+/- 5.6kv & 7kv	100	no	115/230	50/60	5.25	19	36	1997	current
120-500	635942	DIGITEL-MPC	+/- 5.6kv & 7kv	500	no	115/230	50/60	5.25	19	37	1997	current
8-80	635943	DIGITEL-MPC	+/- 5.6kv & 7kv	2X100	no	115/230	50/60	5.25	19	56	1997	current
120-500	635944	DIGITEL-MPC	+/- 5.6kv & 7kv	2X500	no	115/230	50/60	5.25	19	57	1997	current
8-500	635945	DIGITEL-MPC	+/- 5.6kv & 7kv	100+500	no	115/230	50/60	5.25	19	56	1997	current
120-500	635946	DIGITEL-MPC	+/- 5.6kv & 7kv	2X500	no	115/230	50/60	5.25	19	57	1997	current

## Appendix III: Magnet Orientation in Sputter-Ion Pumps

### Introduction:

For an ion pump to operate properly, it must have a magnetic field which meets or exceeds a minimum value and which is precisely oriented parallel to the axis of the anode cells. The magnetic field, in conjunction with the high voltage applied to the pump, causes the electrons inside the anode cells to travel in curved orbits which are smaller in diameter than the anode cells.



1. All magnets, including the Earth, have a North pole and a South pole. A simple compass can be used to determine the polarity of a magnet segment, however, readings should be made away from iron pole pieces.
2. Like poles (N-N or S-S) repel each other and unlike poles (N-S or S-N) attract each other.
3. In an Ion Pump magnet array, the magnet sections must be arranged in a magnetic circuit; that is N-S-N-S-N-S...etc., all the way around the pump.

4. The magnetic field should be between 1000-1800 gauss for most sputter-ion pumps. Higher magnetic fields give somewhat higher pumping speed, especially at low pressure. If the magnetic field is below 800 gauss, performance will be poor, especially at pressures below  $10^{-8}$  torr. See the manufacturer's specifications for the rated magnetic field.

For example, typical Varian style pumps with magnet gaps of approximately 2.5 inches utilize magnetic fields of 1200 gauss.

Typical PE/Ultex style pumps with magnet gaps of approximately 1.5 inches utilize magnetic fields of 1800 gauss.

If the measured value is less than 80% of that specified, you will probably get poor pumping results, especially at low pressures.

5. When assembling an Ion Pump magnet array, the magnets will tend to 'pull' into a correct circuit configuration and 'push' out of an incorrect circuit configuration.

6. In Figure 1, (a cross section of a pump such as a Varian 110 or 140 l/s model), as long as the individual blocks on the magnet assembly are installed correctly, the orientation of the magnet assembly does not matter.

7. In Figure 2, (a cross section of a pump such as the Varian 60 l/s model), the circuit must be completed exactly as shown. If one of the magnet assemblies is installed backwards, the pump will operate with some reduction in speed, but the stray magnetic field will be excessively high, and may interfere with sensitive experiments.

8. In Figure 3, (a cross section of a pump such as a Varian 400 or 500 l/s pump), the most critical of the arrangements is illustrated. If one of the center magnet segments is reversed, so that it doesn't make a proper magnetic circuit, the pumping speed of the pump will be reduced by nearly 50%. If the two outside assemblies are reversed with respect to each other, the pump will operate with some reduction in speed, but the stray magnetic field will be excessively high, and may interfere with sensitive experiments.