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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)

<table>
<thead>
<tr>
<th>Pressure - Torr</th>
<th>10^{-8}</th>
<th>10^{-4}</th>
<th>10^{-2}</th>
<th>760</th>
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<tbody>
<tr>
<td>Pressure Zone</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

Figure 2

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 multimeter. 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 in 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 $3\times10^{-3}$ 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 screwdriver 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.

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.

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

<table>
<thead>
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</tbody>
</table>

Figure 2

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.
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 $1x10^{-5}$ 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)
### Perkin Elmer/Ultek Ion Pump Control Units 1961-1992

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<tr>
<td>6</td>
<td>Ionpak 200 222-0200</td>
<td>5500 2.5 yes</td>
<td>120 60/50 small box</td>
<td>5 1984</td>
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<td>7</td>
<td>5-9 60-056</td>
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<td>115 60/50 cabinet</td>
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<td>8</td>
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<td>13</td>
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<td>117/208/230 60 5.25&quot;</td>
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<td>17</td>
<td>40 60-103</td>
<td>3200 350 yes</td>
<td>115 60 cabinet</td>
<td>80 1961</td>
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<td>4750 350 yes</td>
<td>115 60 8.75&quot; 19&quot;</td>
<td>70 1966</td>
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<td></td>
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<td>19</td>
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<td>4750 350 yes</td>
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<td>21</td>
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<td>22</td>
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<td>23</td>
<td>80-220 222-0530</td>
<td>+/- 5500 250 yes</td>
<td>115/208/230 60 6.5&quot; 19&quot;</td>
<td>70 1977</td>
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<tr>
<td>24</td>
<td>80-220 222-0580</td>
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<td>115/208/230 60 6.5&quot; 19&quot;</td>
<td>70 1977</td>
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<tr>
<td>25</td>
<td>25-270 44-220 222-0600</td>
<td>+/- 5500 220 yes</td>
<td>110/220 6050 5.25&quot; 19&quot;</td>
<td>49 1982 microprocessor</td>
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<td>26</td>
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<td>4750 350 yes</td>
<td>115 60 10&quot; 19&quot;</td>
<td>125 1963 6.5 volts - 50 amps</td>
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<td>27</td>
<td>Boostivac 60-655</td>
<td>4750 350 yes</td>
<td>115 60 10&quot; 19&quot;</td>
<td>125 1964 6.5 volts - 50 amps</td>
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<td>28</td>
<td>Boostivac 224-0620</td>
<td>4750 350 yes</td>
<td>115 60 10&quot; 19&quot;</td>
<td>125 1974 6.5 volts - 50 amps</td>
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<td>29</td>
<td>Boostivac 224-0650</td>
<td>4750 350 yes</td>
<td>208/230 50 10&quot; 19&quot;</td>
<td>125 1974 8.0 volts - 55 amps</td>
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<tr>
<td>30</td>
<td>Boostivac 224-0630</td>
<td>+/- 5500 250 no</td>
<td>117 60 7&quot; 19&quot;</td>
<td>125 1977 8.0 volts - 62 amps</td>
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<td>31</td>
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<td>+/- 5500 250 no</td>
<td>220 50 7&quot; 19&quot;</td>
<td>125 1977 8.0 volts - 62 amps</td>
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<tr>
<td>32</td>
<td>90-450 60-153</td>
<td>3200 1000 no</td>
<td>110 60 cabinet</td>
<td>140 1961</td>
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<td>33</td>
<td>100-1200 60-154-01</td>
<td>4750 1000 no</td>
<td>208/230 60 8.75&quot; 19&quot;</td>
<td>148 1963 with meter relay</td>
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<tr>
<td>34</td>
<td>100-1200 60-160-01</td>
<td>4750 1000 no</td>
<td>208/230 60 8.75&quot; 19&quot;</td>
<td>130 1967 with meter relay</td>
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<td></td>
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<tr>
<td>35</td>
<td>100-1200 60-160-01</td>
<td>4750 1000 no</td>
<td>208/230 60 8.75&quot; 19&quot;</td>
<td>130 1967 with meter relay</td>
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<tr>
<td>36</td>
<td>100-1600 222-0600</td>
<td>4750 1000 no</td>
<td>208/230 60 8.75&quot; 19&quot;</td>
<td>131 1972</td>
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<tr>
<td>37</td>
<td>100-1600 222-0650</td>
<td>4750 1000 no</td>
<td>208/230 60 8.75&quot; 19&quot;</td>
<td>131 1972</td>
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<tr>
<td>38</td>
<td>120-500 222-0630</td>
<td>+/- 5500 720 no</td>
<td>208/230 60 6.5&quot; 19&quot;</td>
<td>130 1977</td>
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<tr>
<td>39</td>
<td>120-500 222-0680</td>
<td>+/- 5500 720 no</td>
<td>208/230 60 6.5&quot; 19&quot;</td>
<td>130 1977</td>
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</table>

*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
<table>
<thead>
<tr>
<th>Item #</th>
<th>Pump Speed liters/sec</th>
<th>Model Number</th>
<th>Output Volts*</th>
<th>Output MA</th>
<th>H.V. Cable</th>
<th>Input Volts</th>
<th>Input Hz</th>
<th>Mounting Height</th>
<th>Mounting Width</th>
<th>Ship** Weight</th>
<th>Orig. Year</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Appendage 921-0006</td>
<td>3200</td>
<td>40 yes</td>
<td>115/230 60</td>
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<td>20</td>
<td>1961</td>
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<tr>
<td>2</td>
<td>Appendage 921-0015</td>
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<td>40 no</td>
<td>115/230 60</td>
<td>cabinet</td>
<td>20</td>
<td>1963</td>
<td></td>
<td></td>
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<td>Appendage 921-0014</td>
<td>3200</td>
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<td>115/230 60</td>
<td>7* 19*</td>
<td>50</td>
<td>1963</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Multiple Pump</td>
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<td>4</td>
<td>8 or 10 921-0011</td>
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<td>150 yes</td>
<td>115/230 60</td>
<td>7* 19*</td>
<td>52</td>
<td>1961</td>
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<tr>
<td>5</td>
<td>Leak Det. 975-0000</td>
<td>3200</td>
<td>150 no</td>
<td>115/230 60</td>
<td>10 1/2* 19*</td>
<td>60</td>
<td>1962</td>
<td></td>
<td></td>
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<tr>
<td>6</td>
<td>15 921-0013</td>
<td>7200</td>
<td>70 yes</td>
<td>115/230 60</td>
<td>10 1/2* 19*</td>
<td>53</td>
<td>1963</td>
<td></td>
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- **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**

*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/Ultrek 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
### TABLE 1: Ion Pump Control Units 1992-1997

<table>
<thead>
<tr>
<th>Base Unit</th>
<th>Model Number</th>
<th>Description</th>
<th>Voltage</th>
<th>Current</th>
<th>Height</th>
<th>Width</th>
<th>Year Status</th>
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<tr>
<td>Base Unit</td>
<td>929-4002</td>
<td>MultiVac Base</td>
<td>+/- 5 to 7.5kV</td>
<td>800</td>
<td>no</td>
<td>110 &amp; 220</td>
<td>50/60</td>
</tr>
<tr>
<td>Base Unit</td>
<td>929-4101</td>
<td>MultiVac Base</td>
<td>+/- 5 to 7.5kV</td>
<td>250</td>
<td>no</td>
<td>90-130</td>
<td>47-63</td>
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</table>

**Addendum: Ion Pump Control Units 1992-1997**

- 8-500 635945 DIGITEL-MPC +/- 5.6kV & 7kV
- 2-80 2220240 IONPAK plus 5.6KV | 8.6 | no | 110/230 | 50/60 | 3.1 | 7.2 | 20 1994 current |
- 2-80 2220242 IONPAK | plus 5.6kV | 8.6 | yes | 110/230 | 50/60 | 3.1 | 7.2 | 20 1994 current |
- 2-80 2220240 DIGI-PAK | plus 5.6kV | 8.6 | yes | 110/230 | 50/60 | 3.1 | 7.2 | 20 1994 current |
- 2-80 2220242 DIGI-PAK | plus 5.6kV | 8.6 | yes | 110/230 | 50/60 | 3.1 | 7.2 | 20 1994 current |
- 8-80 635941 DIGITEL-MPC | +/- 5.6kV & 7kV | 250 | no | 110/230 | 48-62 | 5.75 | 19 | 44 1982 obsolete |
- 8-80 635942 DIGITEL-MPC | +/- 5.6kV & 7kV | 500 | no | 110/230 | 50/60 | 5.25 | 19 | 36 1997 current |
- 8-80 635943 DIGITEL-MPC | +/- 5.6kV & 7kV | 2X100 | no | 110/230 | 50/60 | 5.25 | 19 | 36 1997 current |
- 8-80 635944 DIGITEL-MPC | +/- 5.6kV & 7kV | 200 | no | 110/230 | 50/60 | 5.25 | 19 | 36 1997 current |
- 8-80 635945 DIGITEL-MPC | +/- 5.6kV & 7kV | 100 | no | 110/230 | 50/60 | 5.25 | 19 | 36 1997 current |
# Ion Pump Control Units -- 2010 Catalogs

## Agilent (Varian)

<table>
<thead>
<tr>
<th>NAME</th>
<th>MODEL</th>
<th>HV pos/neg</th>
<th>SS CURRENT</th>
<th>MAX POWER</th>
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<tr>
<td>MiniVac</td>
<td>929-200</td>
<td>5KV</td>
<td>15 mA</td>
<td>21 W</td>
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<tr>
<td>Dual</td>
<td>929-000</td>
<td>3-7KV</td>
<td>100-400mA</td>
<td>100-400W</td>
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<tr>
<td>MidVac</td>
<td>929-000</td>
<td>3,5,7KV</td>
<td>100mA</td>
<td>150W</td>
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## Gamma (PE)

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<th>MODEL</th>
<th>HV pos/neg</th>
<th>SS CURRENT</th>
<th>MAX POWER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digitel SPC</td>
<td>500</td>
<td>3.5-7.0KV</td>
<td>15 mA</td>
<td>20W</td>
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<tr>
<td>Digitel LPC</td>
<td>1500</td>
<td>5.6 OR 7.0KV</td>
<td>250mA</td>
<td>500W</td>
</tr>
<tr>
<td>Digitel MPC</td>
<td>-1</td>
<td>5.6 OR 7.0KV</td>
<td>500mA</td>
<td>500W</td>
</tr>
<tr>
<td></td>
<td>-2</td>
<td>5.6 OR 7.0KV</td>
<td>500mA</td>
<td>1000W Total</td>
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</table>

## Duniway

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<th>NAME</th>
<th>MODEL</th>
<th>HV pos/neg</th>
<th>SS CURRENT</th>
<th>MAX POWER</th>
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<tbody>
<tr>
<td>Terranova</td>
<td>751A</td>
<td>3.5-7.0KV</td>
<td>50mA</td>
<td>50W</td>
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<tr>
<td>Terranova</td>
<td>752A</td>
<td>2x 3.5-7.0KV</td>
<td>50mA Total</td>
<td>50W Total</td>
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<tr>
<td>Classic VA Style</td>
<td>921-0062</td>
<td>3.3KV(+ or 5.2KV(-)</td>
<td>200mA</td>
<td>250W</td>
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<tr>
<td>Classic VA Style</td>
<td>921-0066</td>
<td>3.3KV(+ or 5.2KV(-)</td>
<td>675mA</td>
<td>700W</td>
</tr>
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</table>
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/Ultek 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.
Cleaning and Rebuilding Sputter-Ion Pumps

Introduction:
Duniway Stockroom Corporation rebuilds sputter-ion pumps and pump elements from all original manufacturers as a service to our customers. The process involves removal, cleaning/replacement of all parts and vacuum processing of the rebuilt pump. All deposits are removed, material is outgassed and electrical leakage is minimized. The rebuilt pumps have the same performance and warranty as new pumps. The following information describes the process we use.

Open Pump & Remove Elements
For large pumps, generally above 50 l/s pumping speed, the elements can be easily removed through the throat of the pump. For smaller pumps, the pump body must be cut open to remove the elements. Some small pumps have been designed with weld flanges that permit multiple rebuilding processes. For most small pumps, however, rebuilding is limited to 1-3 times, depending on the design, due to material removed during the opening process.

Disassemble the Element Completely
Anode, cathodes, insulators and support structures are separated and inspected to verify condition. The parts are then cleaned, replaced or treated, depending on their material and condition.

Stainless Steel Parts
Body, anode and other stainless steel parts are glass-bead blasted and acid etched. It is important to use clean, glass beads (not sand blasting). The acid etching is performed by a certified chemical cleaning shop, since the acid, a 35% nitric/3-4% hydrofluoric mix is extremely aggressive. It can attack welds if improperly used and must be handled and disposed of properly. After etching, the stainless steel parts are thoroughly rinsed and protected until re-assembly.

Replace Titanium and Tantalum Parts
Titanium and tantalum cathodes are replaced with new material in most cases. There are a few exceptions to this, but customers will be advised if these materials are re-used.

Ceramic Parts
For Perkin-Elmer/Ultel style pumps and elements, the ceramics are always replaced with new ceramics. For other style pumps, such as Varian, the ceramics are inspected for damage and replaced if necessary, air fired to remove surface deposits, and then vacuum fired.

Vacuum Degas all Element Parts
Stainless steel and ceramics are vacuum degassed at 1000°C. Titanium and tantalum parts are vacuum degassed at 700°C. Vacuum degassing removes both remaining surface contaminants and gasses from the bulk of the material.
Reassemble Elements
The clean parts are reassembled in a laminar flow bench, using clean assembly techniques. Assembled elements are checked for electrical leakage and hi-potted if necessary.

Install the Elements in the Clean Body
The clean elements are installed in the clean pump body. For small pumps, the body is welded back together. For all pumps, the cover flange, with copper pinch-off tube is installed. The pump is checked for leaks on a helium leak detector.

Bake-Out on Vacuum Manifold.
The copper pinch-off is attached to a vacuum manifold, and the pump is baked out at 400°C for 16 hours.

Check for leakage current
While still on the vacuum manifold, the pumps are checked for leakage current and hi-potted if necessary

Pinch off
The copper tube is pinched off with the proper tools. Magnets are installed and the appropriate high voltage is applied. Residual current is checked, it must be below 2 microamps at this point. It is typically below 0.5 microamps.

Clean Exterior
The exterior of the ion pump is glass bead blasted to remove the yellow-brown chrome oxide formed during baking. This step is strictly cosmetic.

Check for Leakage Current
The pump is checked again for residual current; first without the magnets for electrical leakage; then with magnets for residual pressure. Residual current is checked; it must be below 2 microamps at this point. It is typically below 0.5 microamps. Attach inspection tag noting serial number, date, residual current and inspector.

Ship
Properly package pump and/or magnets to avoid damage during shipment.
Notes:

Installing new/rebuilt elements in an old body
If new or rebuilt elements are installed in a used pump body without cleaning the pump body, only about half the improvement in performance will be achieved.

Unsuccessful Attempts to Clean the Pump Yourself
If you attempt to clean the pump and are unhappy with the results, send it to us for rebuilding. We do not charge extra for rebuilding pumps where the user has attempted unsuccessfully to do the job themselves.

Experience and Attention to Detail
The cleaning process is not inherently difficult, however, it does involve proper equipment, facilities and attention to detail. Duniway Stockroom Corp. performs these processes many times every day, so they are easy for us. We use the best materials and our chemical cleaning shop supplier is licensed for proper handling and disposal of hazardous chemicals.

Contacting Duniway Stockroom Corporation
We have multiple ways set up to contact us. We will be glad to answer your questions and help you with your ion pump or other vacuum related questions.

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<thead>
<tr>
<th>Toll Free Telephone:</th>
<th>800-446-8811</th>
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<tbody>
<tr>
<td>Telephone:</td>
<td>650-969-8811</td>
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<tr>
<td>FAX:</td>
<td>650-965-0764</td>
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<tr>
<td>E-mail:</td>
<td><a href="mailto:info@duniway.com">info@duniway.com</a></td>
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<tr>
<td>Internet:</td>
<td><a href="http://www.duniway.com">http://www.duniway.com</a></td>
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Duniway Stockroom Corp.