Instruction Manual

New Duniway Ion Pumps
Pumping Speeds - 10 to 400 liters per second

Choice of:
Diode/Galaxy/Noble Diode Elements
&
Type of High Voltage Feedthrough

10 20 30 50 100 200 400

DUNIWAY STOCKROOM CORP.

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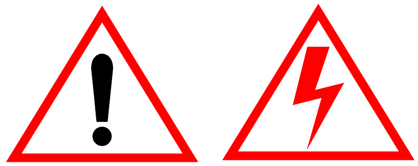
I INTRODUCTION

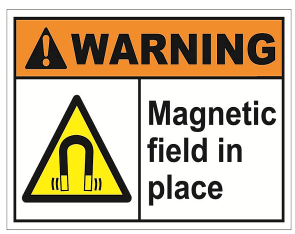
A. Safety Information



Caution:

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

Proper grounding of Ion Pump Control Units, High Voltage Cables Ion Pumps and Systems must be in place to minimize possibility of injury



Caution: The stray magnetic fields from sputter-ion pumps maybe harmful to implanted medical devices if proper procedures are not followed.

B. Overview

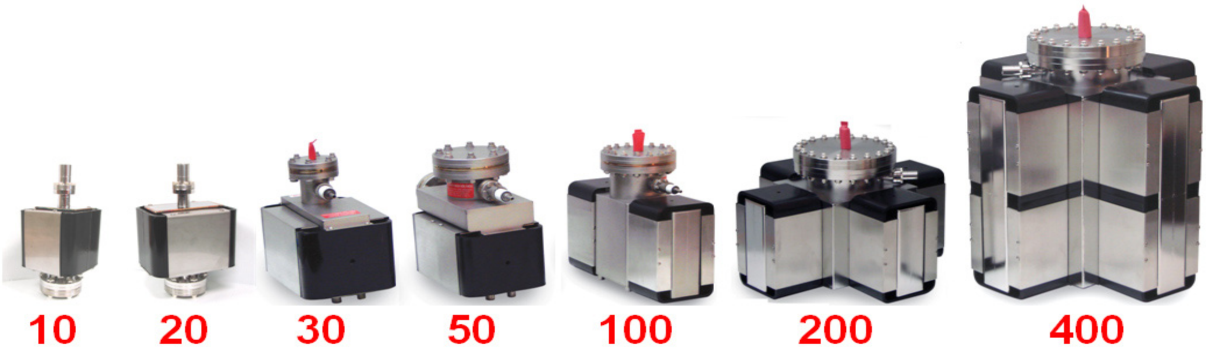
Duniway Stockroom Corp. has a completely updated line of Ion Pump products. We have incorporated our extensive experience with a wide variety of ion pumps to provide an improved offering for our customers.

Features	Benefits
- Improved Element Design	- Higher Pumping Speed/Volume Ratio
- Choice of Element Technology	
Standard Diode	- Low Cost, Long Life for UHV
Galaxy Diode	- Stable Pumping for Air Load/Leaks
Noble Diode	- Stable Pumping for Argon Loads
- Efficient, Modular Design	- Smaller Size
- Lower Profile	
- Choice of High Voltage Feedthrough	- Match Application/Control Unit

High Voltage Feedthrough:	
Standard:	HVFT-5125 Fischer-Style Fault-Safe
Optional:	HVFT-5143 Varian-Style
	HVFT-5120 Varian Starcell Style
	FT-PE-133 PE-Style

Double-Ended configuration available on 200 and 400 l/s models. Please inquire.
All pumps are shipped processed and under vacuum.

C. Ion Pumps-Photos and Part Numbers - Table 1



Ion Pump Related Products

Ion Pump P/N with Magnet	Pumping Speed N_2	Element P/N	Element Qty	Magnet P/N	Magnet Qty
DSD-010-5125-M	10	PE-10-STD	1	MAG-1010	1
DGD-010-5125-M	10	PE-10-GXY	1	MAG-1010	1
DND-010-5125-M	8	PE-10-ND	1	MAG-1010	1
DSD-020-5125-M	20	PE-20-STD	1	MAG-2020	1
DGD-020-5125-M	20	PE-20-GXY	1	MAG-2020	1
DND-020-5125-M	16	PE-20-ND	1	MAG-2020	1
DSD-030-5125-M	30	PE-38-STD	1	MAG-0114	1
DGD-030-5125-M	30	PE-38-GXY	1	MAG-0114	1
DND-030-5125-M	24	PE-38-ND	1	MAG-0114	1
DSD-050-5125-M	50	PE-38-STD	1	MAG-0114	1
DGD-050-5125-M	50	PE-38-GXY	1	MAG-0114	1
DND-050-5125-M	40	PE-38-ND	1	MAG-0114	1
DSD-100-5125-M	100	PE-38-STD	2	MAG-0114	2
DGD-100-5125-M	100	PE-38-GXY	2	MAG-0114	2
DND-100-5125-M	80	PE-38-ND	2	MAG-0114	2
DSD-200-5125-M	200	PE-38-STD	4	MAG-0114	4
DGD-200-5125-M	200	PE-38-GXY	4	MAG-0114	4
DND-200-5125-M	160	PE-38-ND	4	MAG-0114	4
DSD-400-5125-M	400	PE-38-STD	8	MAG-0400	4
DGD-400-5125-M	400	PE-38-GXY	8	MAG-0400	4
DND-400-5125-M	320	PE-38-ND	8	MAG-0400	4

D. Ion Pump Related Products

In addition to the new ion pumps described above, Duniway Stockroom offers a full line of products and services related to ion pumps. Please go to our catalog or web site.www.duniway.com.

- New Varian-Style and PE style Ion Pumps from appendage pumps to 500 l/s versions
- Customized ion pumps and controls for specialized applications
- Re-building services available for all ion pumps and elements.
- Spare parts: magnets, feedthroughs cathodes, insulators
- High Voltage Cables – bakeable, radiation resistant, custom lengths. choice of connectors
- New Terranova Ion Pump Controls with digital display, process control and computer interface
    - o Terranova 751A – Single Ion Pump Control/Display
    - o Terranova 752 – Dual Ion Pump Control/Display
- Other new ion pump controls
    - o IPC-0062 - Medium Ion Pump Control
    - o IPC-0066 – Large Ion Pump control
- Variety of Rebuilt Ion Pump Controls
- Roughing Pumps and Supplies
    - Mechanical Pumps and Oils
    - ForelineTraps
    - Refrigerated Sorption Pumps and Supplies
    - Turbo Pumps

II TECHNICAL SPECIFICATIONS

A. Weight and Dimensions

Pump Speed (L/S)	Flange OD Inches (mm)	Height Inches (mm)	Width Inches (mm)	Depth Inches)mm)	Weight Pounds (kg)
10	2.75 (70)	8.3 (210)	4.0 (100)	4.0 (100)	8.7 (3.9)
20	2.75 (70)	8.3 (210)	4.0 (100)	5.3 (140)	10.8 (4.9)
30	2.75 (70)	7.5 (190)	8.5 (220)	5.3 (140)	23.8 (10.8)
50	4.50 (114)	8.5 (220)	11.0 (280)	5.3 (140)	30.5 (13.9)
100	6.00 (154)	11.5 (290)	14.0 (312)	5.3 (140)	56.0 (25.4)
200	8.00 (203)	11.5 (290)	17.0 (430)	17.0 (430)	105.1 (47.7)
400	8.00 (203)	18.0 (450)	17.0 (430)	17.0 (430)	185.6 (84.3)

Table 2 - Pump Dimensions and Weights

B. Pumping Speed Data for Various Common Gases

Gas Species	Diode Speed % of Rated	Galaxy™ Speed % of Rated	Noble Diode Speed % of Rated)
Nitrogen N_2	100	100	83
Oxygen O_2	70	70	70
Hydrogen H_2	220	220	160
Argon Ar	~1	5	20
Helium He	10	15	15
Carbon Dioxide CO_2	100	100	85
Water Vapor H_2O	100	100	85

Table 3: Relative Pumping Speeds
Various Gases and Pump Element Technologies

C. **High Voltage Supply Output Rating**

It is important to operate the pump with the proper control unit. Standard Diode, Galaxy Diode and Noble Diode ion pumps are rated to operate with a control unit that supplies +5,500 volts DC. Power and voltage versus current curves are shown in Figures 6 and 7.

D. **Vacuum Flange Connection**

The vacuum flange connection from the pump to the vacuum system is a ConFlat type flange. Outer diameter is shown in Table 1 for the different models. The pump comes sealed with a cover flange, a copper gasket and stainless steel screw/nut sets. Connection to the vacuum system requires a new copper gasket. Extra flanges, nuts, bolts, washers and gaskets are available from Duniway Stockroom Corp.

E. **Grounding Requirements**

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

F. **External Environmental Range**

Operating temperature range:	32°F (0°C) to 100°F (38°C)
Maximum baking temperature: non operating, without magnet	775°F (450°C)
Relative Humidity:	0% - 90% non-condensing
Elevation:	-1000 ft. (-300 meters) to +10,000 ft. (+3000 meters)

G. **Vacuum Operation Range**

Maximum Starting Pressure:	2 x 10^{-3} torr (2 microns, 2 millitorr)
	Continuous Operating Range: 10^{-4} torr to below 10^{-11} torr

III Principles of Operation

A: Principles of Operation

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

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

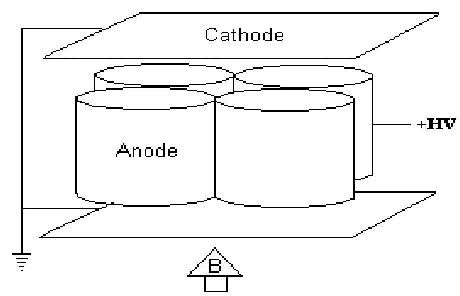


Figure 1: Diode Sputter-Ion Pump Configuration

Figure 2. Galaxy Diode Element

B: Choice of Pumping Element Technology

1. Diode

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

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

2. Galaxy Diode

The new Galaxy ion pump technology uses two titanium cathodes penetrated with spiral patterns which are axially co-located beneath the anode cells. Noble gas ions, such as argon, strike the spiral elements at grazing incidence, resulting in sputtering and neutralization. The neutralized atoms are permanently buried in inactive areas of the pump. An image of a Galaxy cathode is shown below.

1. **Pumping speed for active gases:** The Galaxy pumping speed and capacity for air, hydrogen and water is the same as for the standard diode (two flat titanium cathodes).
2. **Stability for air pumping:** The Galaxy pumping speed for air is stable for all pressures and extended times measured.
3. **Pumping speed for argon:** The Galaxy pumping speed for argon is ~ 10% of its pumping speed for air. This represents ~ 65-70% of the pumping speed for argon of the same geometry DI (Differential Ion), Noble Diode, Starcell or Triode ion pumps. Galaxy operation for argon is stable for all pressures and times measured, except at argon operating pressures above about 2 X 10^{-5} Torr.
4. **Lifetime:** Accelerated and extrapolated lifetime tests with air and argon indicate that the lifetime of the Galaxy elements is in the same range quoted for other ion pump element technologies, i.e. 40,000 to 50,000 hours at an operating pressure of 1 X 10^{-6} torr.

Galaxy elements plus new and rebuilt ion pumps are available from Duniway Stockroom Corp.

3. Noble Diode/Differential

Another variation for stable pumping of noble gases, is the noble diode or differential ion pump. In this diode configuration, instead of two cathodes, both made of titanium, one of the cathodes is made of tantalum. Tantalum is a heavier element (atomic weight 181 versus titanium at 48), and thus sputters at a slower rate than titanium. This differential sputtering again shifts the areas of burial and net build-up of sputtered material to an extent which results in stable pumping of noble gases.

C: Pumping Speed vs Pressure

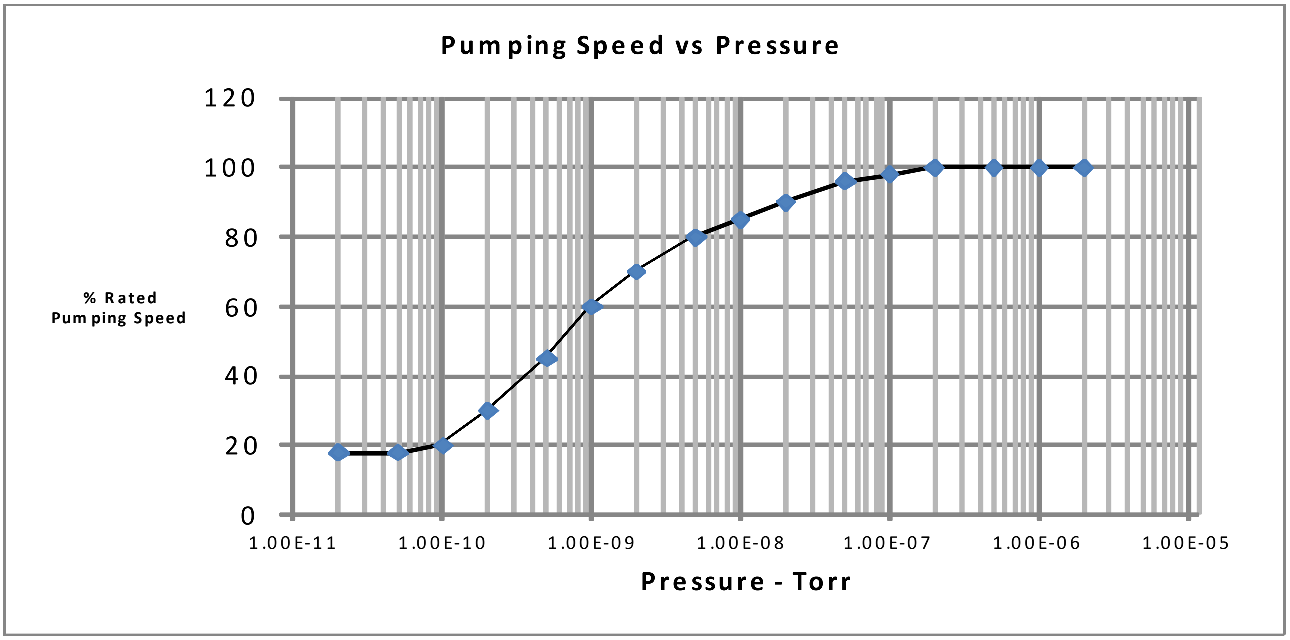


Figure 3: % of Rated Pumping Speed vs. Pressure

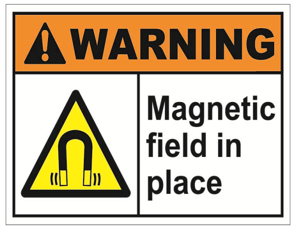
Sputter-Ion Pumps utilize the magnetically confined cold cathode Penning Discharge. Pumping speed is related to many factors, including: Operating Voltage, Magnetic Field, Anode Cell Length and Anode Cell Diameter. These parameters are chosen to optimize the performance in terms of starting, UHV operation and XHV operation.
Figure 3 shows the % of Rated Pumping Speed vs. Pressure for the Duniway line of pumps operating at 5KV.

D: Typical Applications

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

IV Installation & Starting

A. Preliminary Tests



Caution: The stray magnetic fields from sputter-ion pumps maybe harmful to implanted medical devices if proper procedures are not followed.

The sputter-ion pump arrives well protected in a package and under vacuum. After carefully unpacking the pump, inspect it for signs of shipping damage. If any shipping damage is suspected, immediately contact Duniway Stockroom Corp. Before opening the flange with the copper pinch-off, it is advisable to check to be sure that it is still under vacuum, as it was shipped. This is accomplished by properly grounding the pump case (see above), connecting the high voltage connector and applying the operating voltage to the pump. The magnet must be in place. Normally, there will be a brief surge of current, of less than 100 micro-amperes, due to pressure rise during shipment, which will dissipate rapidly. Within a brief time, the current should fall to the micromini level, corresponding to pressure of less than $1x10^{-8}$ torr. If a high current is observed, or if the current does not fall rapidly to less than a few micro-amps, or if no current at all is observed, the pump is probably not under vacuum. Contact Duniway Stockroom immediately.

B. Mounting Requirements

The system should have a mounting flange which is the same as the pump flange: See Table 1 for flange diameters for each pump model. A new copper gasket and the set of bolts and nuts from the original closure flange are required. See Table 1 for pump dimensions for clearance requirements.

C. Grounding Requirements

Due to the hazardous nature of the high voltage used to operate this pump, it is important that proper grounding be present at all times during pump operation. Dual grounding means are provided: The first grounding means is through the high voltage cable shield and connector shell which are connected to the control unit chassis and pump body when installed. Be sure that the "garter spring" around the pump high voltage feedthrough is in place when the high voltage connector is installed. See Figure 6 below for a view of the high voltage feedthrough and connector shell. The second grounding means is through a separate grounding cable which is connected to the case of the control unit and the grounding boss/lug on the pump case.

D. Connecting the High Voltage Supply

Caution:

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

the control unit end and a male banana plug surrounded by a ceramic insulator and grounded metal shell on the pump end. The outer shield of the coaxial cable is grounded at both ends for safety reasons. See Figure 5 for a sketch of the pump-end connection. When connecting the high voltage control unit to the pump, the first step is to be sure that the high voltage control unit is OFF. Then, firmly attach the control unit end of the cable to the control unit. Next, verify that the "garter spring" grounding spring is in place around the groove between the insulator and metal portion of the feedthrough. Then, slip the cylindrical connector shell over the high voltage feed through, being sure that the male banana plug of the connector engages the female receptacle of the high voltage feedthrough and that the cylindrical shell of the connector engages the "garter spring" for grounding purposes. When properly engaged, the connector is firmly in place with little room for movement.

E. Starting the Pump

1. Introduction

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

2. Preparation

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

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

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

3. Control Unit/Power Supply

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

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.

The product of voltage and current at any point in the process gives the power going into the sputter-ion pump. This information is displayed as plot of power versus current. This plot has a power maximum near the middle range of the current capacity. This maximum is called the "power hill", because as the pump current moves either up or down (the same as the pressure moving up or down) it must climb this "power hill". Increasing power means increasing heat to be dissipated, which normally means an increasing gas load due to outgassing. As we will see below (5. Starting), the heating that takes place due to power dissipation has an effect on the starting of the pump.

4. Roughing/Trapping

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

A variety of rough vacuum pumps is available, including rotary mechanical pumps, turbo molecular 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 **turbo molecular pump**. This pumping technology is clean and provides a better pumping speed and lower roughing pressure than other alternatives.

5. Starting

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

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

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

NOTE:

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

V Operation/Protection

A. Introduction

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

In normal operation, the roughing pump valve is closed and the “Start/Protect” switch on the control unit is placed in the “Protect” position. The pump is now protected against a pressure rise above approximately 0.5 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 current vs. pressure curves shown below in Figures 9 and 10. By knowing the current and using the correct curve for that pump and control unit, the pressure can be calculated. In addition, most control units have a “Pressure” scale, which is a logarithmic scale from below 10^{-9} torr to above 10^{-4} torr. Also, a recorder and control signal, with a range from 0 to 100 mV, is normally available for monitoring the pump pressure.

B. Pressure Indication

As discussed above, sputter-ion pump current is proportional to pressure over the operating range. The graphs in Figures 9 below shows a typical plot of Ion Pump Current vs. Pressure for a variety of pump sizes.

The relationship of ion pump current to pressure can be expressed in an approximate fashion by the equation:

$$I/P=10*S$$

Where I is the current in amps, P is the pressure in torr and S is the pumping speed in liters per second. So, for example, for a 50 liter per second pump, the I/P would be 500 amps per torr.

Caution should be used in using ion pump current to indicate pressure, especially at low pressures, due to potential leakage current, as discussed below in “Maintenance”.

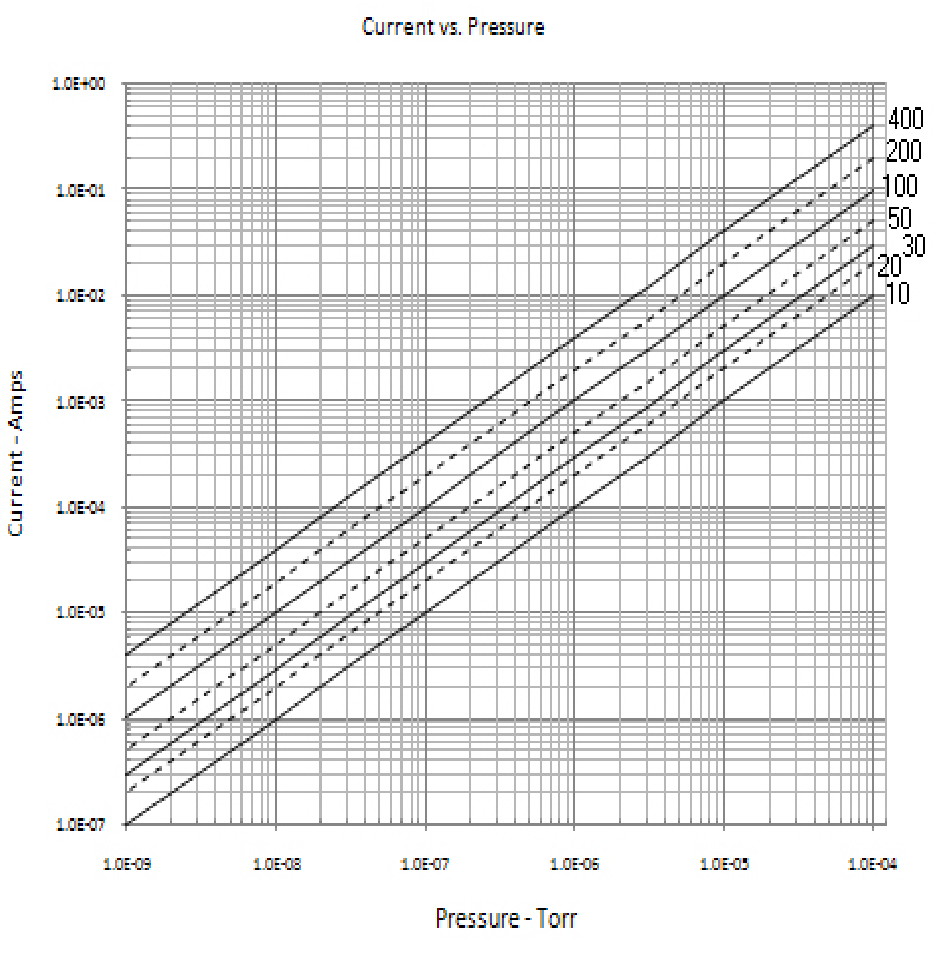


Figure 4: Current vs. Pressure for Ion Pumps 10 - 400 L/S

VI MAINTENANCE

A. Leakage Current & Hi-Potting

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

Resistive Leakage is due to resistive coatings or short circuits of insulating elements in the pump. The presence of this leakage can be detected by using a simple ohm-meter or multi meter on the ohm or resistance scale. When resistive leakage occurs, pumping action is usually reduced or stopped, and the pump or pump elements must be rebuilt. See Section IV-E below for factory maintenance.

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

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

B. Leak Checking

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

C. Magnet Checking

If the sputter ion pump does not seem to be operating with its normal pumping speed, it is possible that there may be a problem with magnet field strength or magnet installation. The following illustration shows proper magnet installation for a variety of pump configurations. Following the illustration is a discussion of procedures for checking magnet installation.

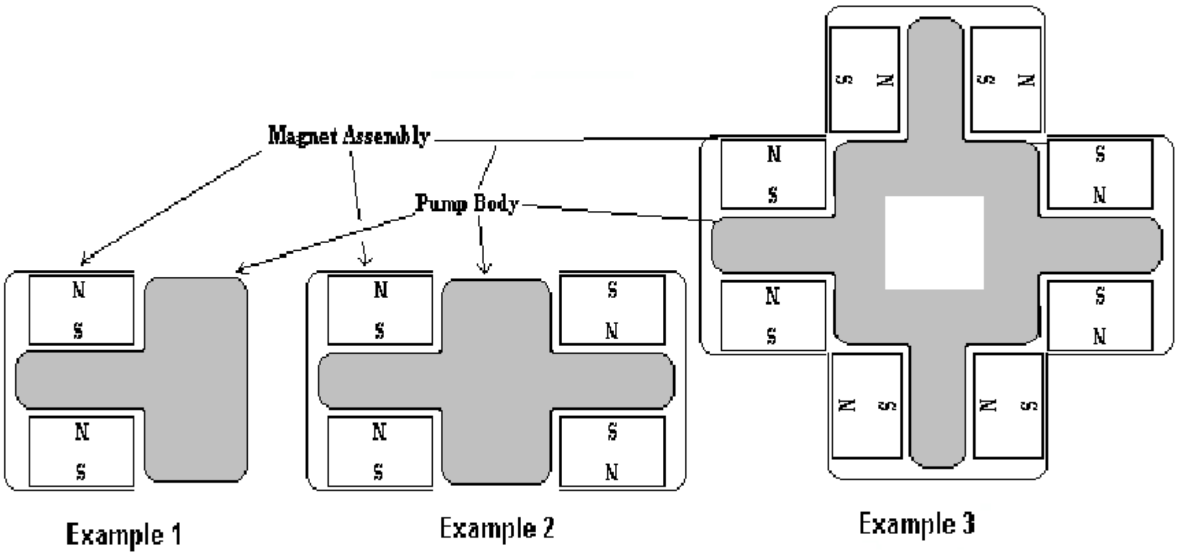


Figure 5: Magnet Orientations for Various Pump Configurations

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

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 11, Example 1, (a cross section of a pump such as the VPE20 and V30 models), 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 11, Example 2, (a cross section of a pump such as the V60, V110/140 and V400/500Varian 60 l/s models), as long as the individual blocks on the magnet assembly are installed correctly, the orientation of the magnet assembly does not matter.

8. In Figure 11, Example 3, (a cross section of a pump such as a V400/500Varian 110 or 140 l/s models), 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.

D. Demounting the Pump

If for any reason, it becomes necessary to remove the pump from the system, be sure to take the proper precautions for personnel and equipment safety. First of all, turn the control unit to the off condition. Then, remove the high voltage connector from the pump. At this point it is a good idea to remove the magnet from the pump to reduce the weight of the pump assemble. Then make sure that the pump is properly supported before starting to remove the bolts from the connection flange. Also, it is not a good idea to let the system up to atmospheric pressure by removing the sputter-ion pump, because any loose material around the gasket may be swept into the system. Loosen slightly all the bolt/nut combinations before completely removing any of the bolts.

E. Factory Maintenance

If it should become necessary to perform maintenance on the pump, such as replacing the pumping elements or high voltage feedthrough, it is best to return the pump, without its magnets, to the factory for maintenance. Please call Duniway Stockroom Corporation for advice and details about sputter-ion pump maintenance and rebuilding.

F. High Voltage Feedthrough

The high voltage feedthrough is mounted on a mini ConFlat flange. If the feedthrough is damaged or develops leakage current during transportation, installation or prolonged use, it can be replaced in the field. For the new line of Duniway Stockroom Ion Pumps, users have a choice of High Voltage Feedthrough to match the application and the specific control unit

High Voltage Feedthrough:

Standard:	HVFT-5125 Fischer-Style Fault-Safe
Optional:	HVFT-5143 Varian-Style HVFT-5120 Varian Starcell Style FT-PE-133 PE-Style

Feedthroughs, gaskets and nut/bolt sets are available from Duniway Stockroom Corp.

G. G 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.

1. 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)

Pressure - Torr

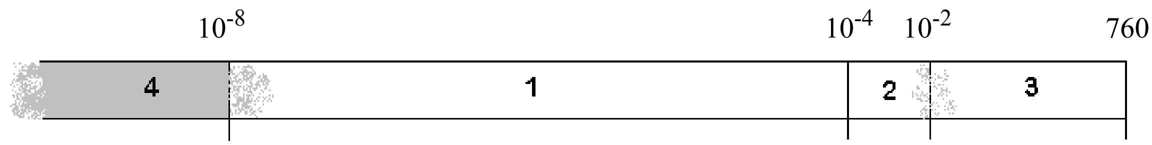


Figure 6: Pressure Zones for Ion Pump Operation

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, Galaxy 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?

2. **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.

3. **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 multi meter. 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.

4. **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.

5. **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.

H. 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.)

1. 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 $3x10^{-3}$ torr. In addition, surfaces in a vacuum system can adsorb many layers of water vapor before they saturate.)

2. 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^{o}C while operating with the magnets on, and to 450^{o}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.)

3. 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.

I. LIFETIME & WARRANTY

Lifetime:

Generally accepted lifetime for ion pumps is 3-4 years at an average operating pressure of 1×10^{-6} torr of nitrogen. Lifetime is proportionately longer at lower operating pressures and shorter at higher operating pressures. Overheating, loads of heavy noble gases (argon, krypton, xenon), frequent venting/roughing cycles and exposure to high vapor pressure materials are also likely to shorten operating lifetime. This lifetime information applies to new ion pumps and rebuilt ion pumps.

Warranty:

Duniway Stockroom new ion pumps are warranted to be free from defects in material and workmanship for a period of one year from the date of shipment. Under this warranty, At our option, we will repair or replace products which prove to be defective under normal conditions of use, during the warranty period. Shipping damage is excluded from the scope of this warranty.

LIMITATIONS OF WARRANTY: The foregoing warranty does not apply to defects resulting from:

1. Improper or inadequate installation or maintenance by the buyer,
2. Buyer supplied interfacing,
3. Unauthorized modifications or misuse,
4. Operation outside of the normal parameters and environmental conditions,
5. Improper site preparation and maintenance.

THE WARRANTY SET FORTH ABOVE IS EXCLUSIVE AND NO OTHER WARRANTY, WHETHER WRITTEN OR ORAL, IS EXPRESSED OR IMPLIED.

EXCLUSIVE REMEDIES: The remedies provided herein are Buyer's sole and exclusive remedies. In no case will Duniway Stockroom be liable for direct, indirect, special, incidental or consequential damages, including loss of profits, whether based on contract, tort or any other legal theory.

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