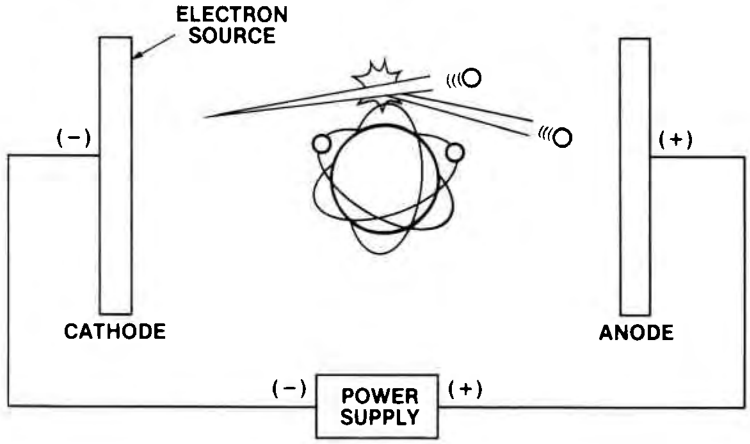
Ion Pump

Let's now make our ion pump by connecting two electrodes to a high-voltage supply. Electron flow will be from cathode to anode as in this drawing. Ions will carry current from anode to cathode. Fewer ions than electrons will be produced so that we can say that the current through the pump is the "ion current."



sputtering

In this drawing, a free electron is attracted to a positively charged anode. On the way to the anode, it collides with a neutral atom, ionizing it. Now two electrons are free to continue toward the anode, increasing the probability of still further ionization. The positively charged ions are then accelerated toward the negatively charged cathode. They may impact the cathode with such force that they stick to the cathode material, and are thereby pumped. As one gas molecule is driven into the cathode, one or more molecules of the cathode is usually released from this surface. This process is called *sputtering*.

The ion pump is also a gas capture pump. It is not designed to pump heavy gas loads. For this reason, it is not generally used alone in high-production applications. Instead, it is more often used in research and analytical applications where there is no need to repeatedly and rapidly cycle the work chamber to atmosphere. When combined with a TSP, it also provides adequate pumping for these applications.

Ion pumps are clean operating devices. They are electronic devices which use no moving parts or oils. It is possible to achieve pressures in the 10^{-11} torr range, with overnight bakeout of the system. The bakeout process drives residual gas off walls. This gas is then pumped by the ion pumps.

In research and analytical applications, the ion pump's cleanliness, bakeability, low power consumption, vibration-free operation and long life make it the pump of choice for most ultrahigh vacuum uses.

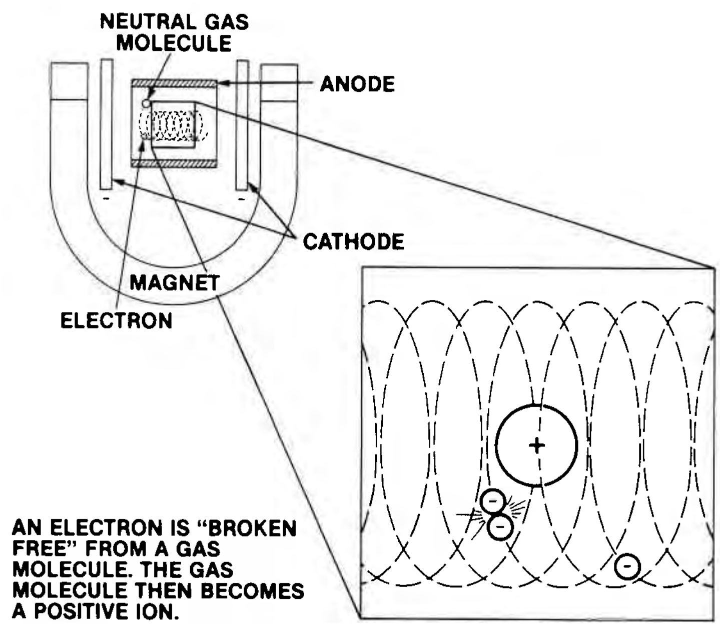
Ion pumps come in various sizes. A small appendage ion pump is used not for pumping down, but for maintaining vacuum conditions in operating devices such as transmitting tubes.

Larger pumps can be used to evacuate small chambers, or several can be connected in parallel with other ion pumps to pump down larger chambers.

Components

A basic ion pump cell consists of two titanium cathodes and an anode. All are placed between the poles of a strong permanent magnet.

How the Pump Works

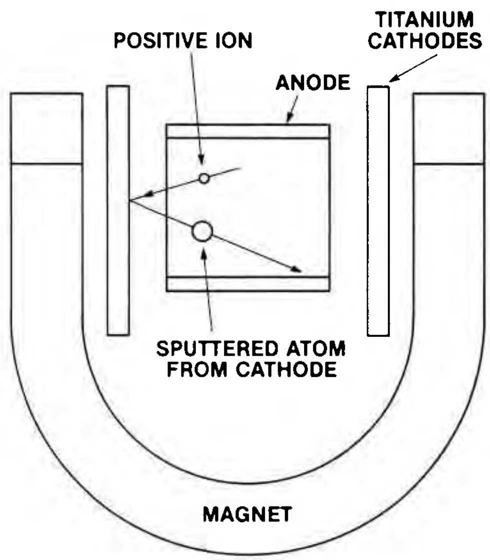


Pump Operation

The magnetic field forces the free electrons to travel in long helical paths instead of straight lines. This increases the probability of collision with molecules on their way to the positively charged anode. This, in turn, increases the ionization probability, and therefore the amount of useful pumping action that can be performed by the pump.

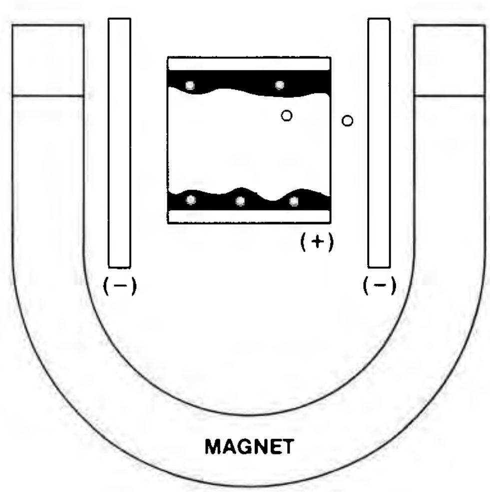
cold cathode discharge

Because of the action of the magnetic field, the electrons do not easily come in contact with the anode. As a result, a "cloud" of electrons is formed in the anode area. This electron cloud becomes fairly stable during pump operation. The electron density is high enough for efficient ionization of gas molecules. Therefore, a hot filament electron source is not needed. So, the name for this process is *cold cathode discharge*.



The positively charged ions, which are relatively heavy particles, are accelerated into the negatively charged titanium cathodes. This impact causes sputtering, or chipping away of the titanium cathode material.

Sputtered titanium deposits onto the internal structure of the pump. There it is available for chemical combination with gas molecules to convert them to solids. Thus we have the needed pumping action.



In addition, a second pumping action takes place. Some of the ionized molecules impact the cathodes with enough force to become buried in them. This burial prevents them from re-combining and becoming a free gas again.

Still another pumping process occurs in the case of hydrogen, which diffuses directly into and reacts with the cathode plate. Also, neutral molecules in the anode regions can literally be buried or "plastered over" by the sputtered cathode material. Complex molecules may also be split in the discharge to smaller, more readily pumped molecules.

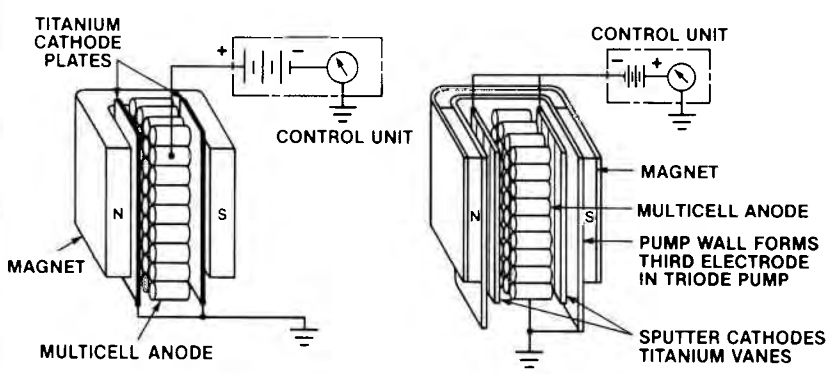
There is a problem with the pump design we have described (also called a diode configuration). Some of the buried molecules can be released again into the vacuum system. This re-release can be caused by heating of the cathodes or reduction of cathode material due to sputtering. It can also be caused by a molecule or atom being physically separated from the sputtered film.

Pumping Characteristics of Different Configurations

Ion pumps are available in different design configurations. Each design has its own special pumping characteristics.

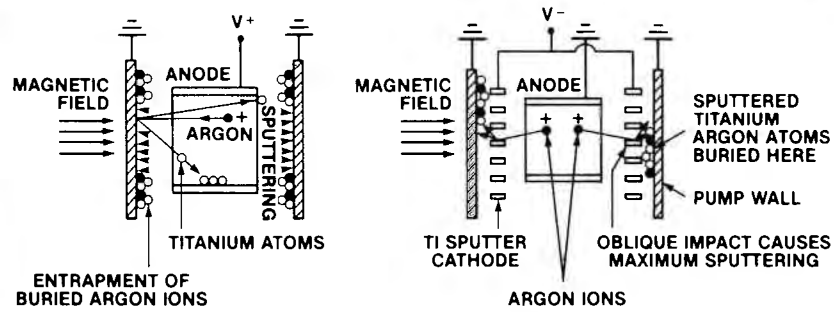
In the diode pump, as we have seen, the ions strike the cathode plate and react with the sputtered titanium.

The triode pump, which is a variation on the diode pump, improves inert or noble gas pumping. Titanium cathodes are in the form of grids. Ions sputter titanium onto the pump walls. This angled impact sputters more titanium than in the diode model and thus furnishes more material for argon or noble gas burial. Because of the electrical arrangement of the pump components, the glow discharge that happens in "starting" the diode pump is typically confined in the triode pump. As a result, the triode pump can be started at slightly higher pressure.



ION PUMP SCHEMATICS

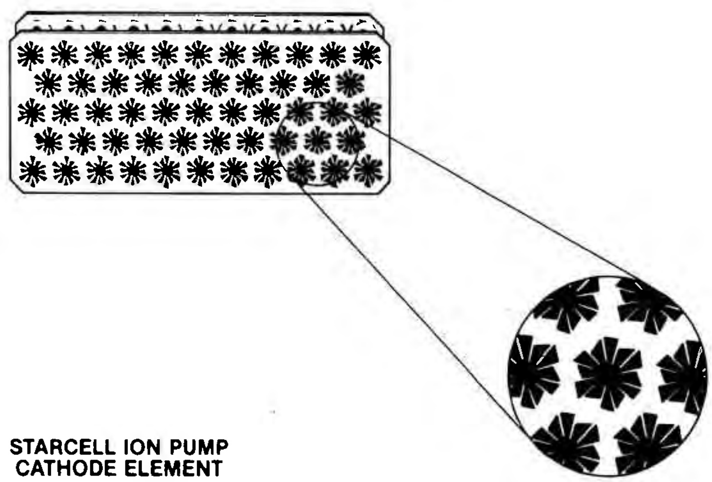
(A) DIODE PUMP (B) TRIODE PUMP



PUMPING MECHANISMS

(A) DIODE ION PUMP (B) TRIODE ION PUMP

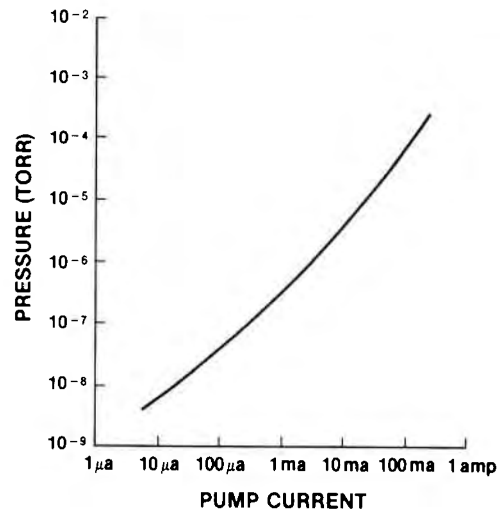
The StarCell™ ion pump provides more noble gas pumping than a triode pump and a stability which is not attainable with a diode element. The StarCell™ pump has an anode structure and two cathode plates. Radially symmetrical, finned cells in the cathode plates are concentric with the anode cells. This increases the probability of higher rebound energy noble gas molecules— an improvement in the efficiency of the noble gas pumping mechanism. Its useful life is greater than diode- or triode-type pumps.



STARCELL ION PUMP CATHODE ELEMENT

Other Characteristics

The ion pump is self-regulating. At the higher pressures, where much ionization takes place, more current flows. At low pressures, less current flows. This characteristic current drain can be used to measure the pressure, or degree of vacuum achieved with the pump. This feature eliminates the need for an ion gauge on the system.



Ion pumps are long lived; the lower the pressure, the longer the life. Once they begin pumping, they quickly lower the pressure to the long-life region. As long as they are not pumping against a leak, they will last for years. Ideally, ion pumps should be started at pressures approaching 10^{-5} torr. At higher pressures, the plasma discharge that is generated minimizes pumping speed and reduces cathode life. A more common and practical approach is to sorption rough the pump to less than 10^{-2} torr before applying the ion pump power. At very low pressures, the time taken to begin the ionization process may be excessively long.

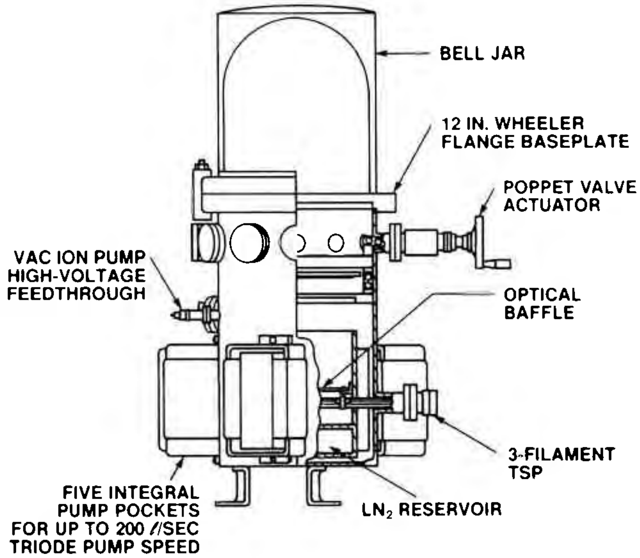
TYPICAL DIODE PUMP SERVICE LIFE

Pressure (Torr)	Life (Hours)
10^{-3}	20
10^{-4}	200
10^{-5}	2,000
10^{-7}	200,000 (over 20 years of constant operation)

Life (Pumping N_2 at 10^{-6} Torr)	
Triode	35,000 hours — approx. 4 years
Diode	50,000 hours — approx. 6 years
StarCell	80,000 hours — approx. 9 years

Vacuum System Use

Ion pumps are typically used in systems which demand ultra-clean, ultrahigh vacuum. This type of vacuum system is pumped to high vacuum or lower pressure and then kept in that condition for long periods of time. A load-lock chamber is often built on the system to allow access to the chamber without bringing the chamber back to air. Typical uses are for electron microscopes, mass spectrometers, and surface analysis, to mention a few.



Maintenance

Very little maintenance can be performed on ion pumps other than an occasional bakeout. When pumping eventually deteriorates to the point where operating pressures can no longer be attained, pump replacement or sometimes anode/cathode assembly replacement is necessary.

Summary

We have discussed the pressure ranges of vacuum pumps and the major types of pumps in each range. By now, you should be familiar with the different types of vacuum pumps—what their major components are and how they work. You have also learned how they are placed in vacuum systems and some general maintenance information.

Let's go on now to gauges. These are major vacuum components that tell you what is going on inside your vacuum system.