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CURRENT PROBLEMS IN RESEARCH

Ionic Vacuum Pumps

Instead of removing the particles of gas, some new pumps simply transfer them to the solid phase.

Lewis D. Hall

With the continued growth and refinement of high-vacuum techniques, there is an increasing interest in methods of obtaining high vacuums by means that will minimize the introduction of contaminants into the vacuum system. In addition, methods are being sought which will make it possible to obtain ultrahigh vacuums without the use of such auxiliary procedures as refrigerating the system.

The terms *high vacuum* and *ultrahigh vacuum* deserve some discussion. As in the case of the analogous terms *high purity* and *ultrahigh purity*, their meanings have changed considerably with time. Today, the term *high vacuum* signifies to most specialists pressures of 10^{-5} mm-Hg or below, and *ultrahigh vacuum* pertains to pressures below 10^{-8} mm-Hg (*1*). As pumping techniques have improved, pressures have been pushed to lower and lower values, and this in turn has led to further refinement of techniques. Those old standbys, the oil diffusion pump and the mercury diffusion pump, are beginning to be replaced in certain applications by devices which can be classified under the general heading of ionic pumps, or, more properly, electron-ion-neutral particle pumps.

As indicated above, the search for improved high-vacuum pumps has been motivated by two main factors: (i) the need for a fluidless pump which will not require a cold trap, in order to eliminate contamination of the system caused by back-diffusion of the pumping fluid, and (ii) the need for a pump which will have a pumping speed greater than zero in the ultrahigh-vacuum region, in order that these extremely low pressures can be obtained without having to refrigerate the entire system. A third requirement, which is fulfilled by the class of pumps to be described here, is that of absence of high-speed mechanical motions.

The kinds of pumps that have been evolved to satisfy these demands are usually termed "ion pumps," because of the fact that the pumping mechanism depends in part at least upon the production of electrically charged particles, or ions. Some of these ion pumps depart radically from the intuitive definition of "pumping," in that gas particles are not pumped out of the system into the atmosphere, but instead are simply transferred from the gas phase to the solid phase inside the system. Such pumps are sometimes referred to as "getter" pumps because their pumping action is similar to the action of getters used to improve the vacuum in electron tubes. It is therefore convenient to generalize the term *pumping* to mean any process by which the number of molecules in the gas phase in the system is caused to decrease. This general definition will be used throughout this article. The term *cleanup* has also been widely used to denote a reduction in pressure caused by electrical or chemical effects, or both, in a sealed system.

Dr. Hall is directing research work in ionization pumping at Varian Associates, Palo Alto, Calif.

History

The earliest recorded observation of electrical pumping was made by Plücker in 1858 (*2*). Plücker stated that oxygen, chlorine, bromine, and iodine reacted with the platinum negative electrode in his discharge tube. The reaction products were then deposited on the glass walls of the tube, according to his interpretation. This view of the pumping mechanism is probably incorrect, in the light of modern knowledge; nevertheless it embodies certain of the phenomena which actually occur in gas cleanup.

An excellent review of the earlier work on gas cleanup in electrical discharge has been given by Pietsch (*3*). Dushman, in his classic treatment of vacuum technique, gives an extensive coverage of the field up to 1949 (*4*). Observations of electrical cleanup were made by many workers over a period of years before any attempt was made to apply the effects to make a vacuum pump. Pietsch alone lists 169 references, among the more interesting of which are Heald (*5*) and Soddy and Mackenzie (*6*).

The kind of apparatus in which cleanup effects were observed consisted in its simplest form of a glass tube with two electrodes, containing a gas at a reduced pressure. A typical tube of this kind, the Crookes tube, is shown in Fig. 1.

From the beginning, it was generally recognized that for gas to be pumped electrically some or all of the following phenomena must occur: (i) ionization; (ii) excitation, that is, dissociation of molecules into atoms and creation of metastable molecules; (iii) sputtering, that is, removal of material from a cathode surface by positive ion bombardment; (iv) chemical or physical reactions of gases with the electrodes; (v) chemical or physical reactions of gases with disintegrated (sputtered) cathode material; and (vi) chemical or physical reactions of gases with the container walls.

The combination of these effects into a device that would serve as a useful

pump has been a long time in coming, but developments have been accelerated in the past few years.

Modern Ionic Pumps

One of the most important single developments in the history of ionic vacuum pumps occurred when Penning developed the technique of a cold-cathode discharge in a magnetic field (*7*). Penning's aim was to produce a device which could be used to measure pressure, and the degree to which he succeeded is shown by the widespread use of his gauge today. The Penning gauge, or Philips gauge, as it is called in this country, uses a high-transparency anode, solid cathodes, and a magnetic field which greatly increases ionization.

Figure 2 shows the Penning gauge as depicted in his original patent (*8*). Electrons which originate anywhere in the volume tend to go to the ring-shaped anode, but are constrained by the magnetic field, about which they spiral and produce other electrons by various processes, directly and indirectly. Because of the magnetic field, which need be only a few hundred oersteds, the discharge persists down to much lower pressures than it otherwise could. One of the concomitant effects observed in the Penning gauge is a reduction in pressure in the gauge due to removal of molecules from the gas phase. This was recognized by Penning and others as a drawback to use of the gauge to measure pressure (*7, 9*). It is obvious that to the extent that a gauge acts as a pump, thereby perturbing the system, it cannot be considered as an absolute standard for pressure measurement.

The use of a magnetic field and an anode which is highly transparent in the direction of the field are powerful aids to the development of a useful ionic vacuum pump. It was not until several years after Penning's invention, however, that a vacuum pump of appreciable speed was developed, based on a discharge in a magnetic field. The first large vacuum pump of this kind was developed by Foster, Lawrence, and Lofgren (*10*).

The essential features of the Foster pump are shown in Fig. 3. Gas is removed from the central section, which is the high-vacuum region, and delivered to the exit sections, which are at higher pressure. The primary electron source is a hollow, hot cathode at one end, which consists of a helix wound with heavy tungsten wire or rod. A discharge is created which is collimated by the magnetic field and extends from the hot cathode to a cold reflecting cathode at the other end. Electrons emitted from the hot filament attempt to go to the walls, which are at anode potential, but are constrained by the magnetic field to travel in spirals back and forth along the tube. As the electrons oscillate, they lose energy by collisions until they are finally collected on the anode walls.

The positive ions which are created in the discharge are little affected by the magnetic field, but are attracted to the cathodes. Some of these ions may combine with the cathodes; others may be neutralized and then pumped out by the forepump. Other processes can occur, such as trapping of neutral particles by material which is sputtered from the cathodes and deposited on the walls.

At low pressures in the central region of the pump, the positive ion supply is insufficient to maintain a discharge of the desired characteristics, and it is necessary to introduce gas through a leak into the cathode region. This gas leak is adjusted to keep the pressure in the hot cathode region above 3×10^{-4} mm-Hg. The pump is usually operated with an exit pressure of 3 to 5×10^{-4} mm-Hg. The lowest central pressure may vary from 0.8×10^{-6} to 6×10^{-6} mm-Hg. The pumping speed is reported to be 3000 to 7000 liters per second.

Some of the disadvantages of the Foster pump are its large size, high initial cost, high power requirements, and short cathode life. Several thousand amperes are required by the magnet coils, and pump life is severely limited by deterioration of the hot tungsten cathode due to positive ion bombardment. Because of these limitations, its use has been confined to certain experiments with particle accelerators.

A pump which appears to be of much more general utility than the Foster pump was developed by Herb, Davis, Divatia, and Saxon (*11*) and described in detail by Davis and Divatia (*12*) and by Swartz (*13*). The Herb pump, or Evapor-ion pump, as it is usually called, is shown in Fig. 4. It utilizes evaporation of titanium, continuously or intermittently, in conjunction with ionization. The pumping action consists in trapping gas particles on the titanium-coated walls.

The metal casing is 12 inches in diameter and about 24 inches high. The connection to the vacuum system may be made at either end of the pump; in Fig. 4 it is connected to the top. The roughing pump may be connected

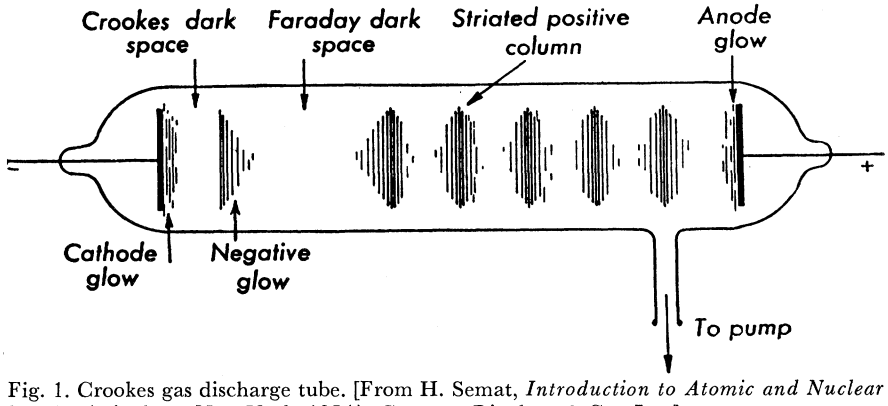

Fig. 1. Crookes gas discharge tube. [From H. Semat, *Introduction to Atomic and Nuclear Physics* (Rinehart, New York, 1954). Courtesy Rinehart & Co., Inc.]

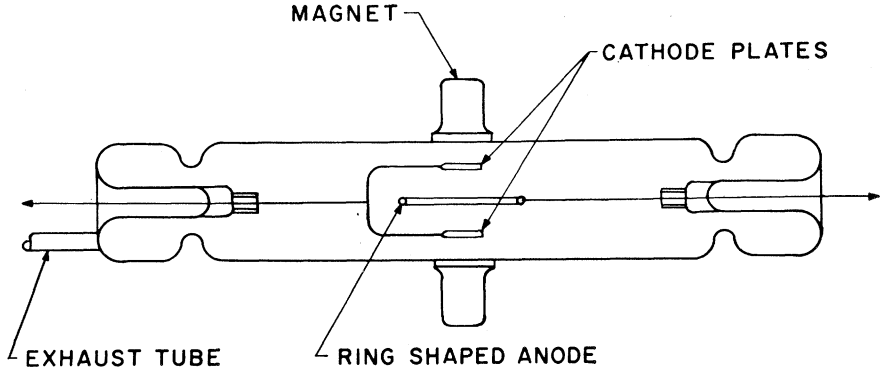

Fig. 2. Penning cold-cathode ionization gauge.

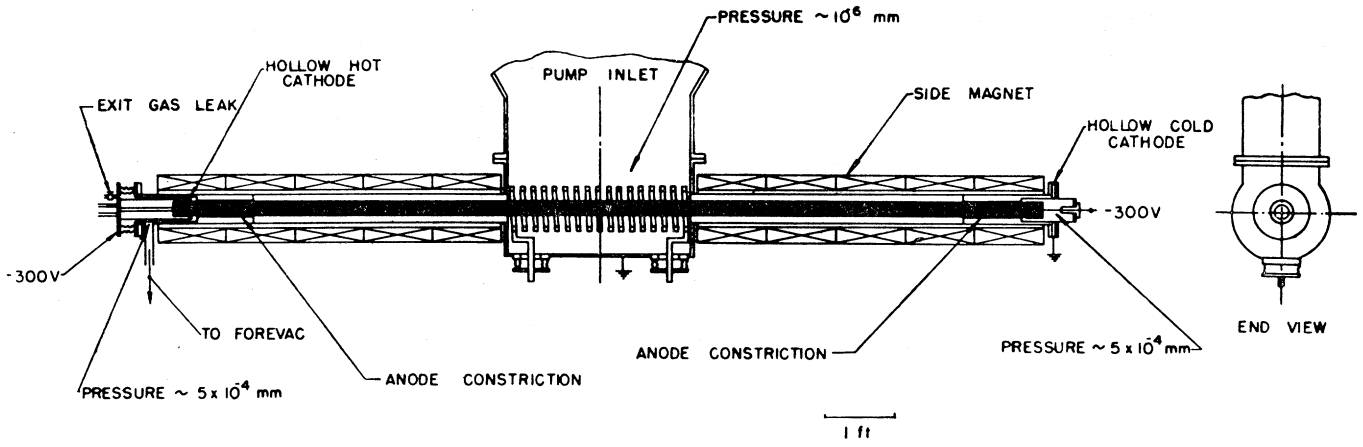

Fig. 3. Foster ion pump.

through a valve either directly to the vacuum chamber or to a 4-inch opening (not shown in Fig. 4) on the side of the Evapor-ion pump. When the Evapor-ion pump is in operation, the valve in the roughing line is usually closed.

A spool of titanium wire is located in the top of the pump. The free end of the wire passes through a feeding mechanism and a tube which guides the wire onto a hot metal post. The feed is actuated through a metal bellows by an external motor. The post is heated by the bombardment of electrons from a single-loop tungsten filament which encircles it. When the wire touches the post, the end melts and also evaporates, coating all exposed pump surfaces. The fresh coating of titanium readily getters active gases such as nitrogen, oxygen, hydrogen, and the carbon oxides. Pumping of the noble gases, such as helium and argon, is believed to require ionization, but this aspect of the pump's behavior requires further investigation. It is certain that a discharge is necessary, but the role of the discharge is by no means fully understood. Electrons for the discharge are furnished by the tungsten filament.

The post and grid are operated at potentials of the order of 1000 volts, and it is therefore necessary to rough out the pump and system to a low pressure, of the order of 5×10^{-5} mm-Hg or below, before attempting to start operation. If this is not done, positive ion bombardment will cause rapid deterioration of the tungsten filament. The problem of establishing favorable conditions for starting the Evapor-ion pump is not simple, and considerable effort has been expended in the direction of making these conditions less severe. The problem is of importance because the ultimate vacuum of a good mechanical roughing pump is of the order of 10^{-3} mm-Hg.

A method of varying the grid potential so as to localize the ionization during starting has been proposed by Moenich, Otavka, and Weberg (*14*). In this technique, the grid, which is ordinarily positive, is reversed in polarity, so as to be negative with respect to the filament. The electrons are driven toward the post rather than accelerated outward into the large volume of the pump chamber. The glow discharge is thus reduced in volume; consequently, less energy is dissipated in maintaining it, and the post is heated more rapidly. In addition, ion bombardment of the filament per unit time should be less severe, because of the smaller extent of the glow discharge. Moenich *et al.* have made another change by adding an extra grid of approximately the same diameter as the filament. This grid is positioned around the post and midway down its length. It

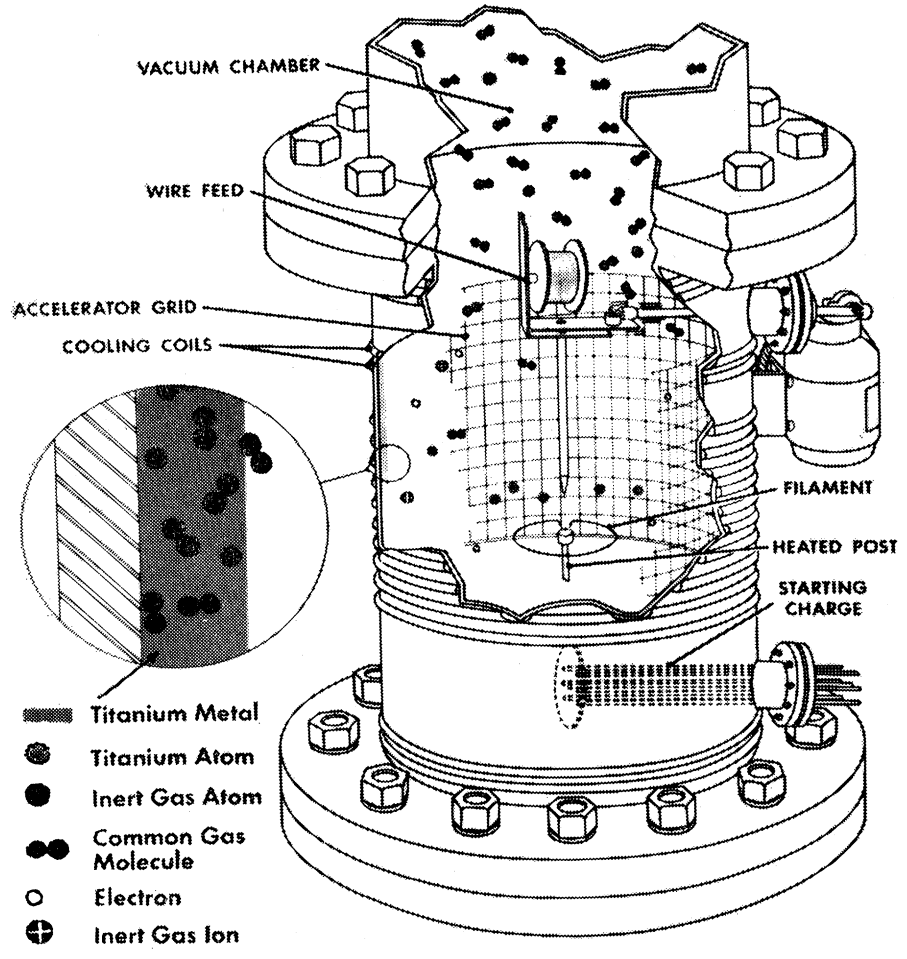

Fig. 4. Evapor-ion pump.

Table 1. Evapor-ion pumping speeds. (Evaporation rate, 5.3 mg of titanium per minute.)

Gas	Speed (lit./sec)	Pressure (mm-Hg)
Hydrogen	3300	$1–7 \times 10^{-6}$
Nitrogen	2000	3×10^{-6}
Oxygen	1000	1×10^{-5}
Carbon monoxide	1000	5×10^{-6}
Air	370	1×10^{-5}
Methane	20	1×10^{-5}
Argon	5	5×10^{-5}

is operated at a negative potential during starting and shields the lower portion of the pump elements from electron bombardment. According to Moenich *et al.*, this modification and that of decreasing the filament diameter have made it possible to start from a rough vacuum of as high as 5×10^{-3} mm-Hg. These changes have not yet been incorporated in commercially available pumps.

Swartz has measured pumping speeds of the Evapor-ion pumps for some common gases, using Dayton's constant-pressure method (*15*). Values are summarized in Table 1, together with the pressures at which the measurements were made.

The low value for argon as compared with active gases is worthy of comment. There is a reciprocal relationship between pumping speeds for a mixture of gases and the speed for the individual components. Therefore, the presence of 1 percent argon in air results in a pumping speed for air which is much lower than that for nitrogen and oxygen.

In order to increase the pumping speed for argon, Alexeff and Peterson added external coils, producing an axial magnetic field, and constructed an elaborate grid system (*16*). With these modifications, they report a pumping speed for argon of 250 liters per second, at pressures between 2.5×10^{-6} and 2.5×10^{-5} mm-Hg.

The length of time the Evapor-ion pump can be operated without maintenance depends on the amount of gas pumped. In tests made at Brookhaven National Laboratory, in which the pump was used to evacuate a simulated accelerator section, Gould estimates that one might expect 2000 days of operation before having to shut down to replace a spool of wire (*17*).

The Evapor-ion pump is an interesting and potentially very useful device. At present the principal obstacles to its widespread acceptance are its high cost and the high cost of associated mechanical pumping equipment which is necessary for most applications. Because of the relatively high vacuum required for starting, only combinations embodying Roots blower mechanical pumps are feasible, and these are quite expensive. However, it is possible that future research of the kind described above may alleviate the starting problem (*14*).

Since the advent of the Evapor-ion pump, small titanium evaporator pumps have been made in several laboratories. One such pump, called the getter-ion pump, is described by Gale (*18*). Figure 5 depicts this pump on a system. In operation, the pump and system are roughed down to a few microns, at which point the filament is heated, thus evaporating titanium. The Penning gauge, which is used to provide ionization and excitation, is then operated, and the combined action of evaporation and discharge reduces the pressure to a low value, of the order of 10^{-6} mm-Hg or below.

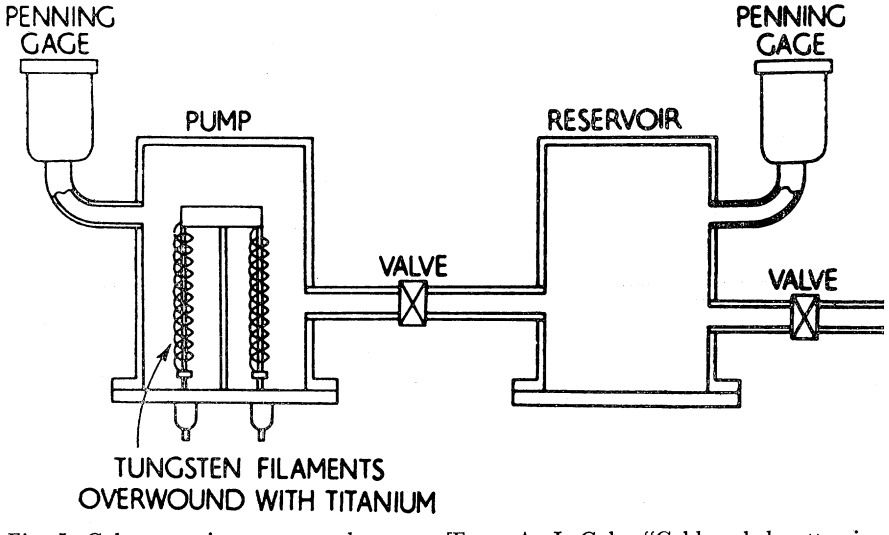

Fig. 5. Gale getter-ion pump and system. [From A. J. Gale, "Cold sealed getter ion pumped supervoltage x-ray tubes," in *C.V.T. Vacuum Symposium Transactions* (Pergamon, New York, 1956). Courtesy American Vacuum Society and Peragmon Press.]

Table 2. Pumping speeds of getter-ion system.

Gas	Speed (lit./sec)
Air	0.016
Oxygen	0.028
Nitrogen	0.018
Carbon dioxide	0.024
Helium	0.009

An interesting feature of such a pump is its ability to pump noble gases. As Gale points out, it is difficult to account for this pumping by the usual explanation that atoms are ionized and then accelerated and imbedded in the getter surface. In this pump, the ionization regions do not "see" the getter surface, and pumping of the noble gases occurs even when an atom must make at least four contacts with the walls before it reaches the getter surface. This therefore suggests that the comparatively long-lived excited states of the neutral atom are important. Pumping speeds for the getter-ion pump are given in Table 2.

My experiments in this laboratory have led to the development of an ionic ultrahigh vacuum pump. The motivation for this work was the desire to develop a small, compact ionic vacuum pump which could be used to replace conventional oil diffusion pumps in the processing of microwave vacuum tubes. Such a pump would have to have a reasonable pumping speed, but speeds of greater than a few liters per second are not required. This is because the limiting factor in tube processing is almost always the impedance represented by the internal structure of the tube and the tubing used to connect it to the vacuum pump.

Experiments with getter-ion pumps were continued for several months in an effort to develop a modification which would be suitable for processing microwave tubes. In the course of this work, several metals were used as evaporants. Of these, titanium, a titanium-manganese alloy, and chromium proved to be effective. However, the useful life of this pump was severely limited by early burnout of the evaporative filament (Fig. 4).

At the same time, experiments were being carried on for another purpose, unrelated to the pumping problem. In the course of this work, which involved

cathode sputtering, it was observed that gas cleanup occurs during sputtering—the same cleanup which had been reported by so many workers over the past hundred years. Since sputtering had also been observed in the Penning ionizer which was appended to the getter-ion pump, a different approach was conceived, and a pump was developed in which the functions of evaporator and ionizer are combined. This pump, shown in Fig. 6, employs a cold-cathode discharge with cathode plates of a reactive metal. Titanium, molybdenum, magnesium, and aluminum are typical cathode materials, and other metals such as vanadium and the rare earths can be used.

Pumping occurs when gas molecules and atoms are taken "out of circulation." The design of an ionic vacuum pump therefore depends on the method by which gas particles are to be trapped. The design of most earlier pumps has been such that the primary pumping action is ascribed to a single cause, the burial of ions in cathode surfaces, although it has been recognized that sputtering may account for some of the observed effects (*7, 19, 20*).

In developing the pump shown in Fig. 6, the intent has been to utilize as fully as possible four interrelated phenomena —ionization, excitation, sputtering, and gettering—in order to produce a pump of much greater speed, lower ultimate pressure, and longer life. It was felt that only by making use of all these effects could a small pump be constructed which would have satisfactory pumping speed for a variety of applications combined with very low ultimate pressure and long life. These properties are aided considerably by designing for maximum gettering, rather than for ion burial.

The discharge creates positively charged particles (ions), atoms (dissociated molecules), and metastable atoms and molecules. High-density parallel ion beams defined by the individual cells bombard the cathodes, ejecting cathode atoms. These sputtered atoms are deposited on appropriately chosen surfaces —the anode walls, and, to a much smaller degree, on the opposite cathode. Atoms and metastable particles which in their random motion strike the sputtered deposits will be trapped by chemical or physical bonds and firmly held. This constitutes the gettering or pumping action.

It is apparent from the data on earlier pumps that ion burial and sputtering are not enough in themselves to provide the desired pump characteristics. To this end, all four of the afore-mentioned effects must be properly integrated. For example, sputtering per se is quite ineffective unless it results in the proper distribution and location of sputtered deposits. The sputtered material must be deposited on appropriately oriented surfaces at anode potential in order to getter properly. Moreover, the density of the ion beam is quite critical, and depends strongly on anode configuration. Neither a ring nor a simple cylinder provides adequate ion current density (concentration over a small area) to compensate effectively for the current of gas particles which continuously arrives at the cathode as a result of random molecular motion. In order to sputter cathode atoms, the ion beam must be dense enough to compete with the molecular beam which tries to keep the cathode covered. On the other hand, if the ion beam is too intense, local melting of the cathode material may result. The cell design is therefore critical.

The cellular anode (Fig. 6) has been found to have many advantages over a ring or a simple cylinder. It increases the effective gettering area, thus increasing the probability of trapping gas particles, and provides increased surface in close proximity to the discharge. This promotes the trapping of excited particles (atoms and metastable particles) before they can recombine into stable states which are less readily gettered. The increased surface area is also of great value in spreading out the getter deposits as widely as possible, thus minimizing the flaking which occurs after long service. It intercepts sputtered atoms, which are thenceforth at anode potential and cannot be resputtered. It increases the effective area of cathode surface from which sputtering occurs, and greatly increases the ion current density, thus further increasing the sputtering rate. It provides a large number of deep field-free regions, increasing the proportion of high-energy ions and thereby increasing sputtering. In addition, it increases the total ion current at any given pressure and permits the discharge to persist to indefinitely low pressures at the applied voltage of 3 kilovolts. The latter feature insures that the pumping speed will not fall to zero until extremely low pressures are reached, since the discharge is responsible for the sputtering which provides the gettering material. It has thus been possible to reach a pressure of 2×10^{-10} mm-Hg after a short bake-out.

Pumping speeds for several gases have

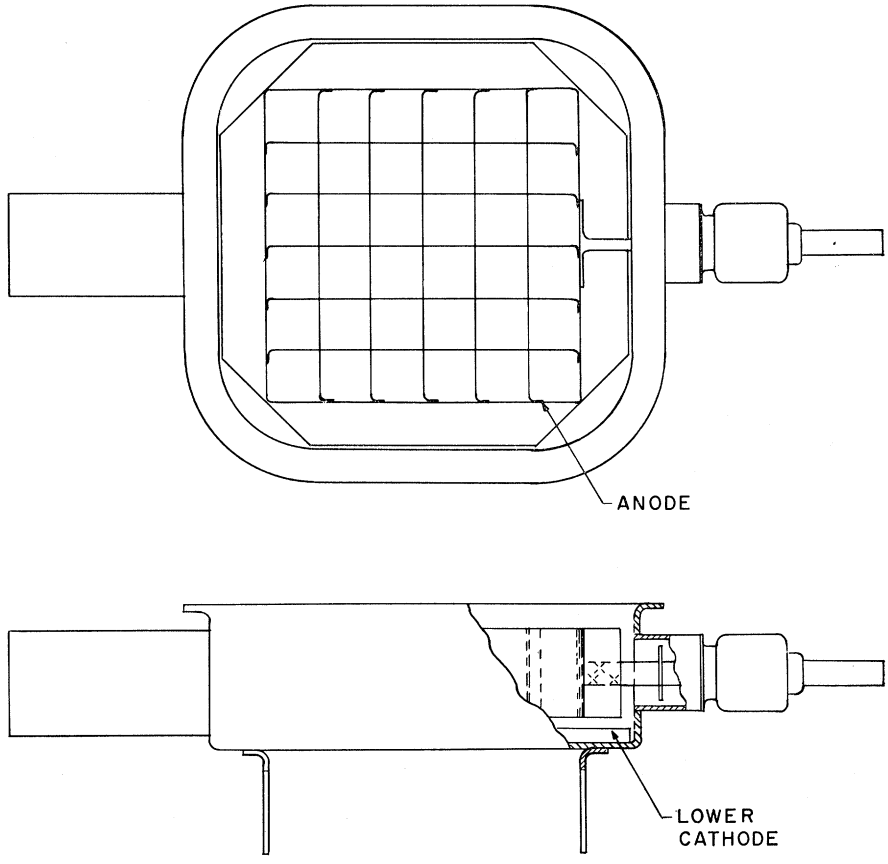

Fig. 6. Varian VacIon high vacuum pump.

Table 3. Varian pump characteristics.

Pressure (mm-Hg)	Speed (lit./sec)	Time to start (min)
Room air		
1×10^{-7} to 1×10^{-5}	10.5	1 to 3
Hydrogen		
2×10^{-7}	11.5	1 to 3
Argon		
2×10^{-7}	9.0	10
Helium		
3×10^{-7}	10.0	10

been measured for a voltage of 3 kilovolts and a magnetic field of 1200 gauss. The measurements are summarized in Table 3, which also gives the starting time—that is, the time required to reduce the pressure in a small system from "rough vacuum" to 2×10^{-4} mm-Hg. Varying the magnetic field over a wide range has little effect on pumping speed.

The ultimate life of the pump will be limited by the supply of cathode metal, and, in this connection, the economical use of titanium which has been observed is of interest. It has been found that in pumping such gases as air, carbon dioxide, and hydrogen, approximately ½ to 1 gas molecule is pumped for each atom of titanium sputtered.

An ionic vacuum pump of considerable interest has been developed by Tsukakoshi (*21*). The Tsukakoshi pump is designed to provide oilless pumping at pressures below 1×10^{-6} mm-Hg, at which the speed of an oil diffusion pump falls off sharply. The pump, shown in Fig. 7, together with an appended ion gauge for pressure measurements, consists essentially of a source of evaporated barium and a hot cathode discharge in a magnetic field. Tsukakoshi does not discuss the ultimate vacuum attainable with this pump, but he gives pumping speed values for several gases. These are summarized in Table 4.

Table 4. Tsukakoshi pump speeds.

Gas	Speed (lit./sec)	Pressure (mm-Hg)
Oxygen	80	3×10^{-7}
Carbon dioxide	50	1.2×10^{-7}
Water vapor	26	2.5×10^{-7}
Hydrogen	8	2.5×10^{-6}

Future Trends

From the accelerated development of ionic pumping devices in the last few years it is evident that we are witnessing the growth of a promising new technology. Pumps have now been built which can compete with oil and mercury diffusion pumps in many respects and which can replace them for some applications.

At this stage it is difficult to predict the possible future form of the ionic vacuum pump. However, it is intriguing to speculate about the directions in which changes might occur. For example, it would be desirable from the standpoint of life to expel gas particles to a region outside the pump in such a way that they could not return. This would eliminate saturation effects. Such a design would require some sort of "one-way valve" for gas ions, through which they could pass to the outside but could not return. An experiment along these lines was performed in this laboratory. A bundle of small-diameter tubes with the axis of the bundle aligned with the axis of the anode in a Penning-type pump was used. It was hoped that in this way, ions would pass through the tubes at a much greater velocity than that with which molecules would drift back. The region outside was pumped with a mechanical pump. The experiment was a failure, for various reasons, but it is felt that the approach may yet yield results. In considering any such ion-ejection system, however, it should be remembered that in an "open" system of this kind, one of the chief advantages of a sealed-off pump is lost—namely, invulnerability in the face of a power failure.

A future ionic pump of the evaporative- or sputter-type may use some metal which is even more reactive than those presently available. It has been reported by Hum that gadolinium shows a much faster pumping effect than other metals in vacuum evaporation (*22*). Unfortunately, the present price of gadolinium metal is prohibitive.

It seems certain that the ionic vacuum pump of the future will employ a magnetic field as well as an electric field, because of the much greater ionization and excitation which are produced. It seems quite probable that, as indicated by present trends, many different designs will emerge, each with its own range of applications. The future of ionic vacuum pumps, like that of ion propulsion and magnetohydrodynamics, appears to be filled with attractive possibilities.

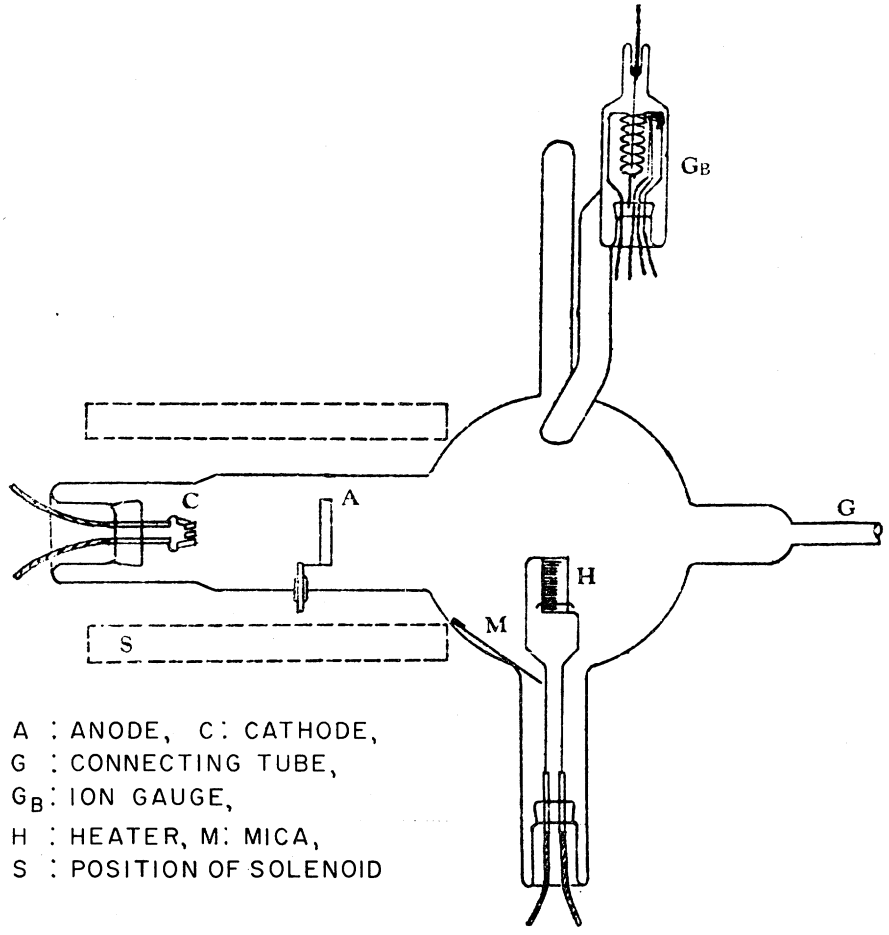

Fig. 7. Tsukakoshi ion-barium pump.

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Role and Status of Anthropological Theories

How successful has anthropology been in producing its own theories? or even in borrowing them?

Sidney Morgenbesser

The progress of anthropology in the last hundred years has evoked, even from critical observers of the state of the social sciences, well-deserved admiration (*1*). Developments in data collection and interpretation, subtle employments of logical and mathematical techniques, a spate of monographs that tax the patience even of the most Alexandrian of librarians, all prove that the phrase "a trained anthropologist" is not a contradiction in terms.

Despite these advances, it is debatable whether the theories employed by anthropologists need win our assent. Concomitantly, it is questionable whether such terms as *culture, cultural integration, role,* and others which appear in such theories are as indispensable for a proper explanation of societal factors as many anthropologists claim.

The first point to note is that there is no universal agreement among anthropologists about the role and relevance of any of the theories currently employed. There is even room to doubt whether anthropologists have any theories at all. British anthropologists have insisted that the concept of social structure introduced by Radcliffe-Brown (*2*), developed by Evans-Pritchard, and now the subject of an interesting monograph by the late and too-little-read S. F. Nadel (*3*) provides them with a rock upon which to build. But a concept is not a theory. Many American anthropologists, moreover, find that Radcliffe-Brown's statements are either opaque or are merely developments of some trite sociological points that Durkheim made long ago (*4*). Not to be outdone in gallantry, British anthropologists find American theoretical anthropology to be either an obsession with the workings of a mystic entity labeled "culture," or applied psychology (*5*). Lest the reader think that I am recording a series of transatlantic insults, I shall quote the words of a long-respected American anthropologist, provoked by an anthology of American anthropological writings: "Some two generations ago," writes Paul Radin, "the great English legal historian (Maitland) declared that anthropology would very shortly have to choose between being history or nothing. Maitland was wrong. . . . Anthropology did not become history, nor did it ostensibly become nothing. In fact, it became everything, and seemed to have taken its etymological meaning literally" (*6*).

These dour notes serve a function. They suggest that it would be helpful to consider anthropological theories under two headings—psychological ones employed by American, and sociological ones employed by British, anthropologists. Since there are Americans in the English camp, and Britishers in the American, this division should not be taken too seriously.

The employment by anthropologists of psychological theories, especially of learning theory (*7*), might evoke surprise.

Uses of Learning Theory

A score of years ago the journals were replete with articles attempting to establish the independence of the social sciences in general, and of anthropology in particular, from psychology. Some merely insisted that cultural data cannot be accounted for on the basis of psychological principles alone. Others went further and suggested that anthropologists disregard the findings of psychology and direct their attention to the interaction of biological and cultural phenomena. Still other articles, like Kroeber's, seemed to suggest that culture is a unique superorganic entity with laws and properties of its own. Culture was the hero and psychology the villain of the drama, and not to anthropologists alone. In a famous chapter in *Experience and Nature,* John Dewey suggested that philosophers test their theories of human nature in light of the teachings of anthropology about culture and its influence. As the writings of Leslie White prove, such themes have not entirely disappeared from the literature of anthropology (*8*). But they are much rarer. Today more anthropologists couple the term *culture* with the word *learned,* or one of its cognates, or else drop the term *culture* and refer merely to "learned behavior." And since learning theory is part and parcel of the science of psychology, we have, despite earlier protestations, not merely an alliance between anthropology and psychology but a threatened domination of the former by the latter.

This turn of events is not too hard to explain. When anthropologists criticized the relevance of psychology, they were primarily refuting the thesis that infor-

The author is assistant professor of philosophy at Columbia University, New York.