Feb. 22, 1966 L. A. DAVIS ETAL 3,236,442

IONIC VACUUM PUMP

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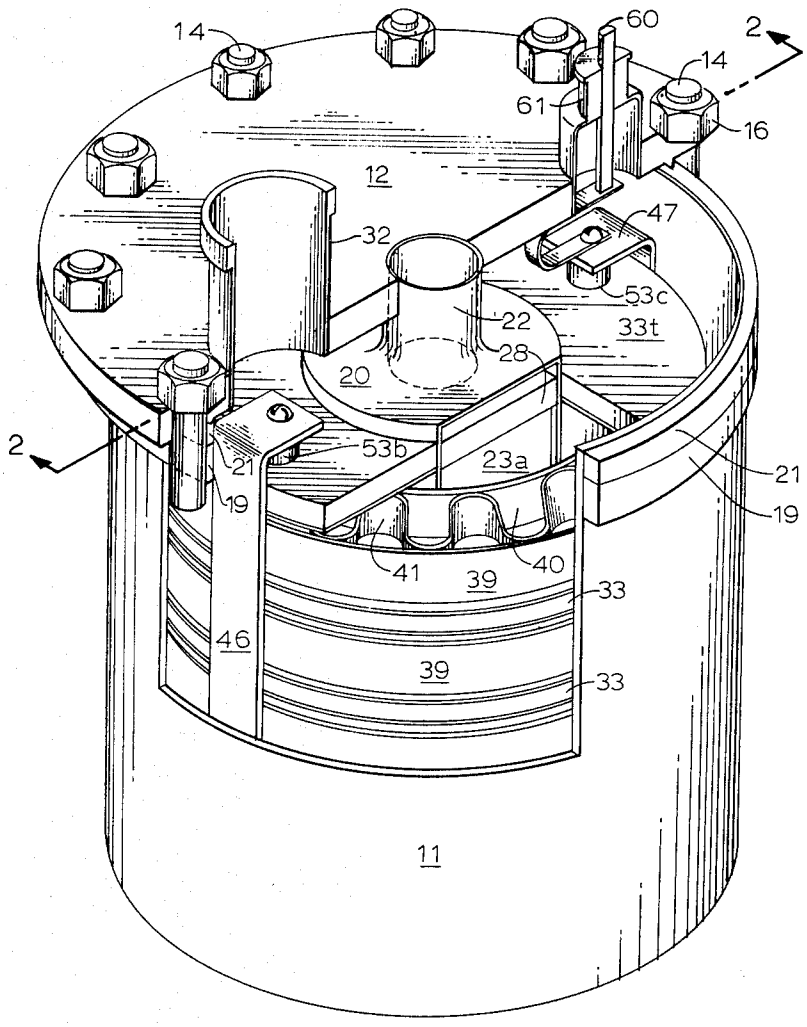


FIG. 1

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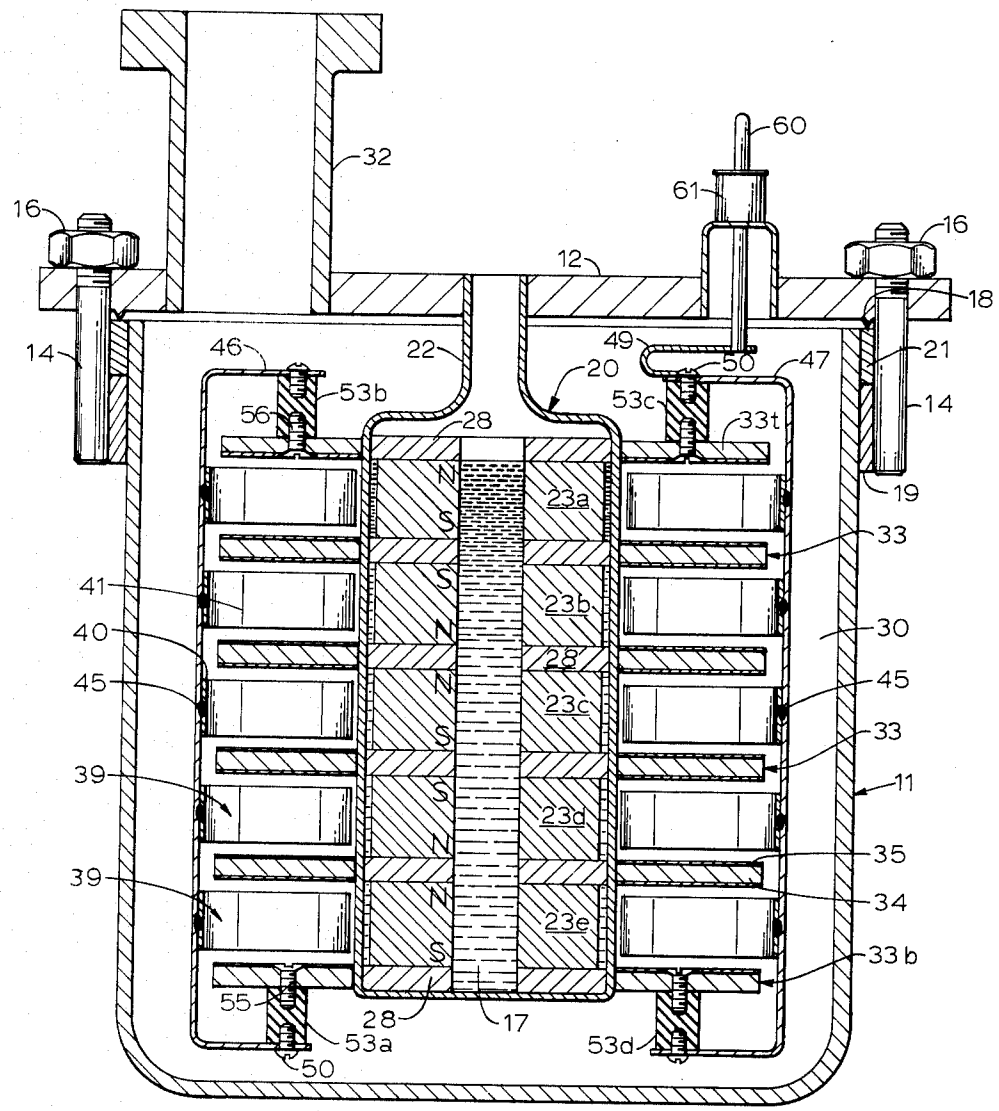


FIG. 2

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IONIC VACUUM PUMP

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15 Claims. (Cl. 230—69)

This invention relates to an ionic vacuum pump and more particularly to such a device utilizing a cold cathode discharge which is capable of achieving an evacuation of gas to extremely low pressure levels.

In achieving the extremely low pressures required in such devices as vacuum tubes, linear accelerators and the like, ionic pumps are generally utilized. With this type of device, mechanical pumping is first used to evacuate most of the gas, and then the final pumping action is achieved electronically in what has become to be known in the art as "ionic pumping." In most ionic pumps of the prior art, a glow discharge is generated by placing a high potential between an anode and cathode contained within the chamber to be evacuated. The anode and cathode are both made of a reactive metal such as titanium. Electrons emitted from the cathode are accelerated at high velocity towards the anode. The electrons collide with gas molecules thereby producing ionization of such molecules. The gas ions so formed bombard the cathode causing atoms to be "sputtered" (knocked off) the surfaces thereof. These sputtered atoms are attracted to the anode and there form stable chemical compounds with active gas atoms remaining in the chamber.

In these devices of the prior art, it has been found that a great increase in pumping efficiency can be achieved if a magnetic field is applied to the electrons flowing between the cathode and anode. The application of such a magnetic field causes the electrons to take a relatively long circular path which causes them to collide with a great many more gas molecules than if a direct path were followed. A typical device of the prior art in which such ionic pumping is achieved is described in Patent No. 2,755,014 issued July 17, 1956, to W. F. Westendorp et al. With this type of device, ultra high vacuum pumping can be achieved.

Prior art devices have a significant limitation in that it takes a relatively long period of time to achieve the desired pumping action. This severely curtails the effective utilization of the pump. It has been found that the major factor limiting the pumping speed is the over heating of the reactive metal cathodes during the high ion current plasma discharge when the ionic pumping is first started after the mechanical pumping has been completed. Such heating releases gas formerly trapped by ion burial and physical absorption from the previous pumping cycle causing a substantial increase in the ion bombardment of the electrodes thereby resulting in a high pressure equilibrium condition. It therefore is apparent that pumping efficiency could be increased substantially if this heating action could be minimized. While this problem has been recognized, the provision of completely adequate cooling means has been discarded in the prior art as being too complicated to be feasible.

Further, in achieving the desired circular motion of the electrons, high strength permanent magnets have generally been utilized in the devices of the prior art. Such magnets while completely effective in producing the desired circular electron path, tend to be rather costly and in addition are generally rather heavy and bulky. The magnets generally utilized also have the disadvantage that they produce stray magnetic fields. This presents a problem in the utilization of such a prior art pump to evacuate equipment while it is operating, such as in the case of linear accelerators, in view of the fact that this type of electron

beam concentrating equipment will not function properly with stray magnetic fields present.

The device of this invention overcomes the above enumerated shortcomings of prior art ionic pumps by providing simple yet highly effective means for cooling the pump and utilizing a periodic magnetic stack for generating the desired magnetic field, such stack being comprised of relatively inexpensive compact and lightweight magnet units. The periodic magnet stack highly concentrates the flux and produces few or no stray magnetic fields, which might adversely affect the operation of equipment in the vicinity.

The above enumerated improvement is achieved in the device of the invention without resorting to an expensive or complicated configuration. The device of the invention is capable of being constructed of simple, relatively inexpensive components which can be readily disassembled and reassembled for the replacement of components such as for example, cathode and anode units.

The desired cooling is achieved in the device of the invention by utilizing a cold trap which is centrally located within the pump housing. In this cold trap, is contained a cryogenic type refrigerant. Also contained within the cold trap is the periodic permanent magnet stack. The vacuum chamber is located between the walls of the cold trap and the walls of the container.

Externally concentric with the magnet assembly within the vacuum chamber are a plurality of alternately positioned anode and cathode members. The cathode members are each attached to a separate pole piece unit and these pole piece-cathode assemblies are supported in the housing by the magnetic force of the magnet stack. The anode members are connected to bracket members which are supported on the end cathode-pole piece members. Both the anode and cathode members are thus magnetically supported.

It is therefore an object of this invention to provide an improved ionic vacuum pump.

It is another object of this invention to provide an ionic vacuum pump which can readily be assembled and disassembled.

It is a further object of this invention to provide an ionic vacuum pump capable of higher efficiency and substantially faster pumping action than prior art devices.

It is still another object of this invention to provide an ionic vacuum pump of simple configuration in which cryogenic cooling is provided.

It is still another object of this invention to provide an ionic vacuum pump in which a periodic permanent magnet stack is utilized to generate a magnetic field and the anode and cathode members are supported by the magnetic force of the stack.

It is still a further object of this invention to provide an ionic vacuum pump of high efficiency which is both simple and economical to fabricate.

Other objects of this invention will become apparent from the following description taken in connection with the accompanying drawings of which

FIG. 1 is a perspective view with partial cutaway section of a preferred embodiment of the device of the invention, and

FIG. 2 is a cross sectional view taken along the plane indicated by the line 2—2 in FIG. 1.

Referring now to the figures, cylindrical housing **11** which is fabricated of a non-reactive metal such as stainless steel is utilized to house the device. Housing **11** has a cover **12** which provides an airtight seal for chamber **30** which is formed therein. Cover **12** is removably attached to the housing by means of bolts **14** which are fixedly attached to collar **19** and nuts **16** which matingly engage the threaded top portions of the bolts. Collar **19** is slidably mounted on housing **11** so that it can be

removed from the housing along with the bolts. Collar **21** which is fabricated of a soft metal such as copper is fixedly attached to housing **11** as, for example, by brazing. The sealing action is achieved by means of knife edge seal **18** which tightly abuts against soft collar **21** when nuts **16** are tightened down.

Fixedly attached to cover **12** in a gas tight joint therewith is container **20** which is fabricated of a non-reactive metal such as stainless steel. Such attachment may be achieved by any suitable means such as, for example by welding. Container **20** serves as a cold trap, and in operation, a cryogenic liquid **17** such as liquid nitrogen is held therein. The top portion **22** of container **20**, the end of which is exposed to the atmosphere, preferably is restricted as in the bottleneck configuration shown in the figures to minimize the evaporation of the cryogenic liquid.

Within container **20**, is a periodic permanent magnet stack which includes toroidal shaped magnets **23***a*–**23***e*. The magnets are arranged in a periodic array with their poles positioned as indicated in FIG. 2. This in effect provides a parallel aiding configuration for adjacent magnets which, as well known in the art, gives a very high flux concentration with minimal leakage, thereby substantially eliminating stray magnetic fields. Excellent results have been achieved with ceramic toroidal magnets fabricated of a low permeance material such as barium ferrite. Such ceramic type magnets are available, for example, from the General Magnetic Corp., Detroit, Michigan. Sandwiched between the magnets and at the top and the bottom of the stack are washer shaped pole pieces **28** which are fabricated of magnetic material. The magnet stack and the associated pole pieces rest freely inside container **20** and are not attached thereto. They are placed inside the container when it is fabricated and are not removable therefrom. As these units seldom need replacement even after long periods of operation, such construction is entirely practicable.

Each of magnet members **23***a*–**23***e* has a slot therein (not shown) running from the center of the magnet through to the wall of container **20**. This is to permit the cooling liquid **17** to flow through to the walls of the container to cool the cathode members adjacent thereto.

Located between the outer wall of container **20** and the inner wall of housing **11** is vacuum chamber **30**. Vacuum chamber **30** is connected to the equipment to be evacuated by means of flange member **32** which is fixedly attached in gas tight relationship to cover **12**. Located within vacuum chamber **30** are cathode-pole piece assemblies **33**. These assemblies which are washer shaped and are externally concentric with container **20**, comprise inner magnetic pole pieces **34** and outer cathode pieces **35** which are fixedly attached to the pole pieces as, for example, by spot-welding. Pole pieces **34** are fabricated of a highly magnetic material while cathode pieces **35** are of a reactive metal such as titanium.

Cathode-pole piece assemblies **33** are held in position between the magnet units **23***a*–**23***e* opposite pole pieces **28**. Assemblies **33** are held in position centered between the magnet units by virtue of the magnetic force of such magnets, a flux path being provided from the north pole of each magnet through an adjacent pole piece **28** thence through an adjacent cathode pole piece **33**, from there through an associated anode member **39** to the next succeeding pole piece **33**, and thence back through a centrally located pole piece **28** to the south pole of the magnet. Thus, an efficient flux path is provided through the electron flow area to produce maximum magnetic effect in deflecting the path of the electrons. This magnetic flux also holds the cathode assemblies **33** in position.

Anode assemblies **39** are ring or washer shaped in configuration and are arranged between the cathode assemblies **33** in external concentricity with container **20**. Anode assemblies **39** comprise a pair of oppositely positioned cylindrical members **40** between which a corrugated member **41** is contained. Corrugated member **41** is fixedly attached to cylindrical members **40**, as for example by welding. Members **40** and **41** are fabricated of a reactive metal such as titanium.

Anode assemblies **39** are spot welded at points **45** to bracket members **46** and **47** to form a unitary assembly. Bracket members **46** and **47** are attached by means of screws **50** to support insulators **53***a*, **53***b*, and **53***c*, **53***d* respectively. Insulators **53***a*, **53***d* are attached to the bottom of cathode-pole piece assembly **33***b* by means of screws **55**, while insulators **53***b* and **53***c* are attached to the top cathode-pole piece assembly **33***t* by means of screws **56**. The anode units are thus supported on the top and bottom cathode-pole piece assemblies which in turn are held in place by the magnet stack. Both the cathode and anode assemblies are thus magnetically supported.

Bracket **47** also acts to conduit high voltage to the anode assemblies and is connected to high voltage terminal **60** by means of connector member **49**. The feed through assembly **61** for terminal **60** provides a high vacuum seal which assures that there is no air leakage to chamber **30**. End cathode-pole piec assemblies **33***b* and **33***t* have no cathode pieces **35** on the ends facing insulators **53***a*–**53***d* and act to shield these insulators and high voltage terminal **61** from sputtered material which might otherwise accumulate thereon and cause the high voltage to short circuit.

In operation, flange member **32** is attached to the equipment to be evacuated in gas-tight relationship therewith. Evacuation is first accomplished by mechanical pumping to the best of the capabilities of a suitable mechanical pumping device (not shown). A high voltage potential, e.g. in the neighborhood of 5,000 volts is then placed between terminal **60** and the wall of housing **11**. This causes an electron flow between cathode members **35** and anode members **39**. The paths the electrons take between the cathode and anode members is increased substantially by the magnetic action of the magnet stack **23***a*–**23***e* which imparts a circular path to such electrons causing them to collide with a substantially greater number of gas molecules than if a direct path were taken.

The positive ions produced by the collision between the gas molecules and the electrons are attracted to the surfaces of cathode members **35** and bombard the surfaces of these cathode members sputtering off atoms therefrom. During the initial stages of operation, when there are a relatively large number of gas molecules in chamber **30**, this bombardment action is quite heavy and tends to cause the cathodes to heat up substantially. This heating tends to release gas which was formerly trapped by ion burial and physical absorption. In the device of this invention, such heating is minimized by the cooling action of cryogenic coolant **17**, and such addition of gas to chamber **38**, which would greatly slow up the pumping action, is thereby substantially eliminated. Experimentation indicates that in the device of the invention, the same degree of evacuation can be achieved in ten minutes that without cooling would take an hour and a half. It is also indicated that the cooling action achieved in the device of the invention tends to prolong the useful life of anode and cathode units, improves the efficiency of the magnet stack, and enables a higher degree of evacuation. The coolant evaporates through the open top of container **20** and can readily be replaced as required.

The cathode-pole piece and anode assemblies can be removed for replacement merely by loosening and removing nuts **16** and taking cover **12** off housing **11**. The anode and cathode units can readily be disassembled by detaching the screws holding together the bracket members and their associated insulators.

Thus, the device of the invention provides a simple and compact yet highly efficient ionic vacuum pump. A highly concentrated magnetic field having minimal

stray fields is provided by means of a relatively inexpensive magnetic stack, this stack also being used to support the anode and cathode assemblies. A marked increase in the speed of pumping action is achieved by virtue of the utilization of cryogenic cooling.

While the device of the invention has been described and illustrated in detail, it is to be clearly understood that this is intended by way of illustration and example only and is not to be taken by way of limitation, the spirit and scope of this invention being limited only by the terms of the following claims.

We claim:

1. In an ionic pump,
a pump housing,
a container centrally located within said housing,
means for generating a magnetic field located within said container,
a cryogenic coolant contained within said container,
a vacuum chamber being formed between the outer walls of said container and the inner walls of said housing,
an anode assembly and a cathode assembly contained within said vacuum chamber, and
means for supporting said anode assembly and said cathode assembly in external concentricity with said container.

2. In an ionic pump,
a pump housing,
a container located within said housing,
means for generating a magnetic field located within said container,
a cryogenic coolant contained within said container,
a vacuum chamber being formed between the outer walls of said container and the inner walls of said housing,
an anode assembly and a cathode assembly contained within said vacuum chamber, and
means for supporting said anode assembly and said cathode assembly in external concentricity with said container, said supporting means comprising said means for generating a magnetic field.

3. In an ionic pump,
a pump housing,
a container located within said housing,
means for generating a magnetic field located within said container, said means for generating a magnetic field comprising a periodic permanent magnet stack,
a cryogenic coolant contained within said container,
a vacuum chamber being formed between the outer walls of said container and the inner walls of said housing,
an anode assembly and a cathode assembly container within said vacuum chamber, and
means for supporting said anode assembly and said cathode assembly in external concentricity with said container.

4. In an ionic pump,
a pump housing,
a container located within said housing,
means for generating a magnetic field located within said container,
a cryogenic coolant contained within said container,
a vacuum chamber being formed between the outer walls of said container and the inner walls of said housing,
an anode assembly and a cathode assembly contained within said vacuum chamber, said anode assembly and said cathode assembly being washer shaped, said cathode assembly comprising a washer shaped member fabricated of magnetic material sandwiched between a pair of washer shaped members fabricated of a reactive metal, and
means for supporting said anode assembly and said cathode assembly in external concentricity with said container.

5. An ionic vacuum pump comprising
a housing,
cover means for said housing,
container means centrally located within said housing, said container means having aperture at one end thereof said aperture passing through said cover means,
a periodic permanent magnet stack contained within said container means,
a coolant contained within said container means,
a vacuum chamber being formed between the outer wall of said container means and the inner wall of said housing,
a plurality of cathode-pole piece assemblies, said cathode pole piece assemblies being externally concentric with said container means, each of said cathode-pole piece assemblies being held in place magnetically between a pair of adjacent magnetic poles of said magnet stack,
a plurality of anode assemblies, each of said anode assemblies being interposed between a pair of said cathode-pole piece assemblies, and
means for supporting said anode assemblies on at least one of said cathode-pole piece assemblies.

6. The pump as recited in claim 5 wherein said means for supporting said anode assemblies comprises a pair of brackets fixedly attached to each of said anode assemblies, and insulator means for attaching said brackets to the uppermost and lowermost cathode-pole piece assemblies.

7. An ionic vacuum pump comprising
a housing,
covers means forming a gas tight seal for said housing,
container means centrally located within said housing, said container means having an aperture formed at one end thereof, said one end of said container means passing through said cover means,
a periodic permanent magnet stack contained within said container means,
a coolant contained within said container means,
a vacuum chamber being formed between the outer wall of said container means and the inner wall of said housing,
a plurality of integrally formed washer shaped cathode-pole piece assemblies, said cathode-pole piece assemblies being externally concentric with said container means, each of said cathode-pole piece assemblies being held in place magnetically between a pair of adjacent poles of said magnet stack,
a plurality of washer shaped anode assemblies, and
means for holding said anode assemblies together to form an integral unit, said anode assemblies being interposed between said cathode-pole piece assemblies.

8. The pump as recited in claim 7 and additionally including means for attaching said anode assemblies holding means to a pair of said cathode-pole piece assemblies.

9. The pump as recited in claim 7 wherein said container, said housing and said magnet stack are cylindrical in shape and are in concentricity with each other and said cathode-pole piece and anode assemblies.

10. The pump as recited in claim 7 wherein said anode assemblies each comprise a pair of concentric cylindrical members and a corrugated plate member positioned between said cylindrical members and fixedly attached thereto, said plate member forming a ring in concentricity with said cylindrical members.

11. The pump as recited in claim 7 wherein said magnet stack comprises a plurality of torroidal magnet units.

12. In an ionic pump,
a pump housing,
a cylindrical container centrally mounted in said housing,
magnet means for generating a magnetic field located within said container,
a cryogenic coolant contained within said container

cover means for forming a vacuum chamber between the outer walls of said container and the inner walls of said housing,

a plurality of alternately spaced anode and cathode-pole piece assemblies contained within said vacuum chamber, said anode and cathode assemblies being washer shaped, and

means including said magnet means for supporting said anode and cathode-pole piece assemblies in a stacked arrangement in external concentricity with said container.

13. An ionic vacuum pump for producing an ultra high vacuum comprising

a housing,

a cover for said housing,

a container fixedly attached to said cover substantially at the center of said cover, said container having an open end, said open end protruding through said cover,

means for removably attaching said cover to said housing in gas tight relationship thereto to form a gas tight chamber between the walls of said container and the walls of said housing,

a coolant contained within said container,

a plurality of cathode members fabricated of reactive metal located in external concentricity to said container,

pole piece members fixedly attached to said cathode members,

a plurality of anode members fabricated of reactive metal interposed between said cathode members and in external concentricity with said container,

means for connecting a high voltage potential between said anode and cathode members,

means for mounting said anode members on at least one of said cathode members in insulated relationship thereto, and

magnet means contained within said container for generating a magnetic field to cause electrons flowing between said cathode and anode members to follow a circular path and to magnetically hold said pole piece members, thereby supporting said cathode and anode members.

14. The pump as recited in claim 13 wherein said magnet means comprises a periodic permanent magnet stack.

15. The pump as recited in claim 13 wherein said coolant comprises a cryogenic liquid.

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