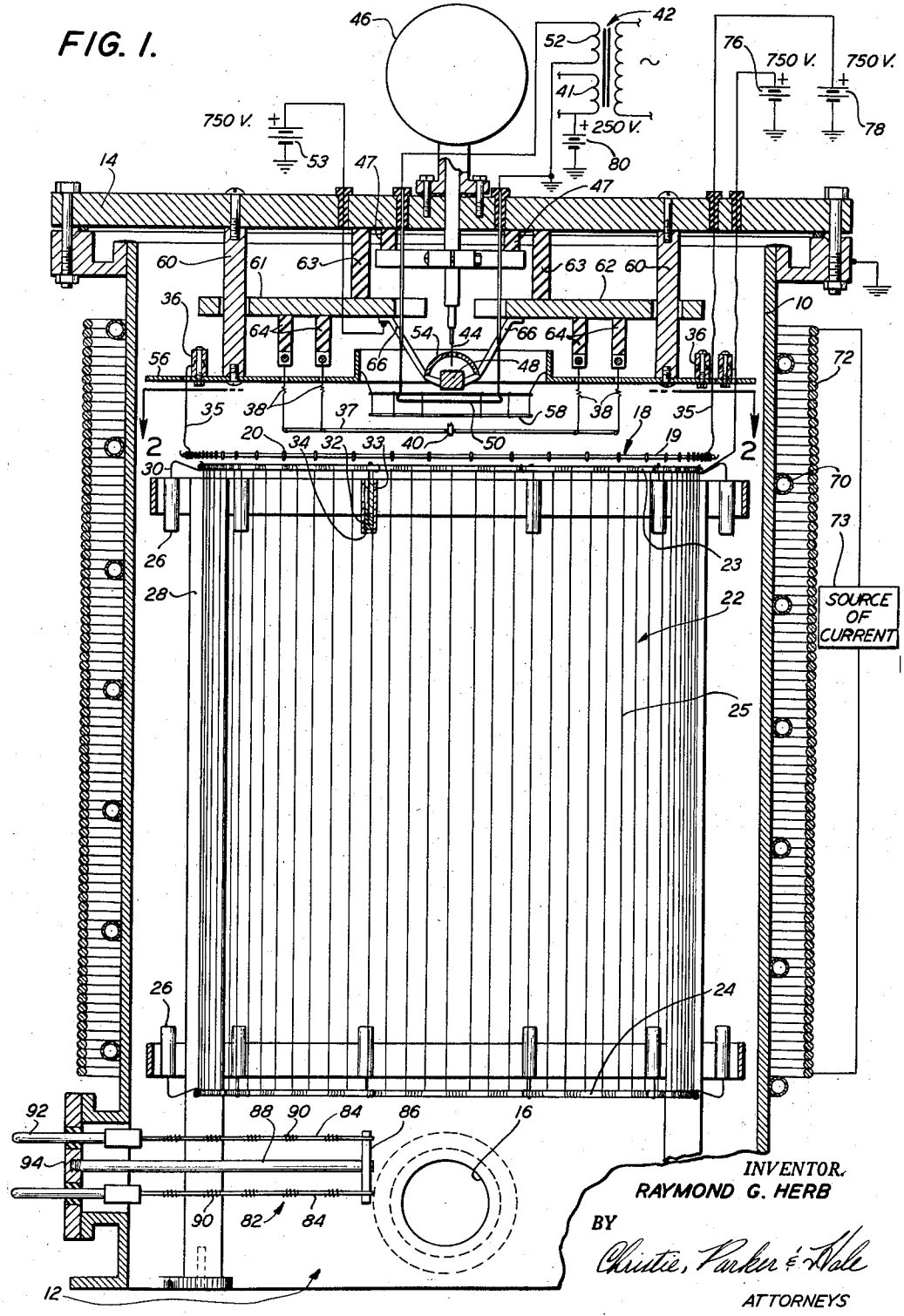
May 26, 1959 R. G. HERB 2,888,189

VACUUM PUMP

Filed March 23, 1956 2 Sheets-Sheet 1

FIG. 1.



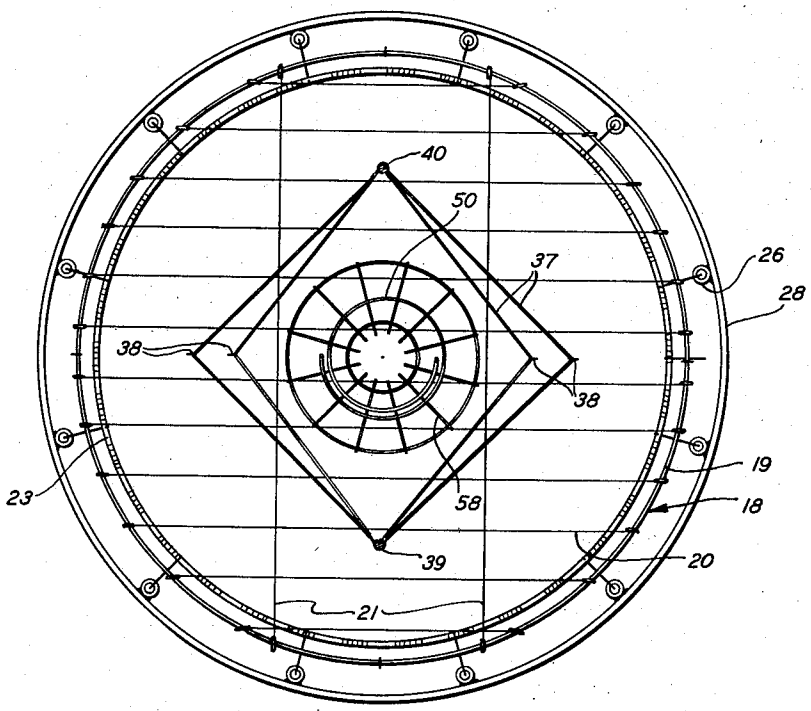
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FIG. 2.



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VACUUM PUMP

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Application March 23, 1956, Serial No. 573,522

17 Claims. (Cl. 230—69)

This invention relates to improvements in vacuum pumps which are capable of producing and maintaining a high vacuum.

My copending application Serial Number 546,025, which was filed on November 10, 1955, now Patent No. 2,850,225, discloses methods and apparatus for producing and maintaining a high vacuum by employing ionization and gettering techniques. Pumps of this type can pump at exceptional speeds while maintaining a high vacuum entirely free of organic or mercurial vapors.

In accordance with the disclosure of the aforesaid patent application, gas molecules are ionized by electron bombardment and they are driven to a collector surface. Gettering material is evaporated and deposited on the collector surface, and the deposition of the gettering material is continued so that the getter traps the gas and secures it to the collector surface and so that the getter buries the gas which has been previously deposited on the collector surface. The reactive gases may be pumped by the gettering operation without ionization of the gas molecules. However, the ionization operation is desirable in order to provide efficient pumping action for other types of gases.

In accordance with the embodiments of the invention which are disclosed in the aforesaid patent application, a thermionic electron emitter is located along the central portion of the chamber which is to be evacuated, and a pair of concentric cylindrical anode grids are located between the thermionic emitter and the walls of the chamber. The electrons are caused to move back and forth between the two concentric anode grids, and they ionize or dissociate the gas into components which can be trapped by a gettering substance. The ionized or dissociated gas molecules are driven toward the wall of the housing where they are trapped and buried by the gettering material.

The pumping apparatus which is disclosed in the aforesaid patent application has a rather slow pumping speed for the inert gases, such as argon or helium. Probably the slow pumping speed is due to inefficient use of the ionizing electrons.

The pumping speed of pumps of this general type is greatly improved by the apparatus of the present invention. By way of example, the apparatus which is disclosed in the aforesaid patent application provided a pumping speed of nine liters per second for argon, one of the inert gases, whereas the apparatus of the present invention provides a pumping speed of 250 liters per second for argon.

In accordance with a preferred embodiment of the present invention, the electrode means which defines the space in the chamber in which gas is to be ionized or dissociated has an electron-permeable end portion which is located adjacent a source of electrons for directing electrons into the ionization space, and it has an electron-permeable body portion which is disposed approximately perpendicularly with respect to the end portion. The body portion of the electrode means is located adjacent

a collector surface, and it is employed to drive the ionized or dissociated gas to the collector surface. This geometry for the electrodes provides a large space in which the gas may be ionized or dissociated. A thermionic electron emitter, which is distributed over a large area, provides electrons which are driven into the ionization space so as to bombard the gas molecules.

Preferably the arrangement for evaporating a gettering substance is located at one end of the electron-permeable electrode structure, and preferably it is provided with a reflector device for directing the gettering substance toward the surface on which the gas is collected.

In order to achieve maximum pumping speed, it is desirable to cool the surface on which the gas is collected so as to enhance the action of the gettering material. It is also desirable to provide a magnetic field in the space in which the gas is to be bombarded by electrons, with the magnetic field serving to cause the electrons to travel in spiral paths when they tend to move across the lines of magnetic flux.

It is believed that the improved action of the present pumping apparatus is largely due to the geometry of the pumping apparatus. Many other factors affect the pumping speed, and one such factor of importance is the use of a reflector in conjunction with the apparatus for evaporating the gettering substance. The reflector may serve to break up the particles of gettering material so that the gettering material is deposited on the collector surface in the form of very small particles.

The invention is explained in more detail with reference to the drawings, in which:

Fig. 1 is a side elevation in section of a preferred embodiment of the pumping apparatus, and

Fig. 2 is a sectional view along line 2—2 of Fig. 1.

In the arrangement illustrated in the drawings, the pumping apparatus is located in a housing comprising a cylindrical body member **10** having an inlet port **12** at one end and an end closure member **14** at the other end. By way of example, the cylindrical body member **10** and the closure member may be composed of stainless steel. These members define a chamber of approximately cylindrical shape from which gas is to be removed. The chamber may be provided with a valved port **16** located in the lower portion of the chamber for coupling the chamber to a forepump for use in reducing the pressure in the chamber before the ionization and gettering actions are initiated.

In this embodiment of the invention, the electron-permeable electrode structure is arranged in two portions. The first portion **18** comprises an annular ring **19** across which a plurality of wires **20** are strung. A pair of wires **21** are woven among the other wires so as to keep them from vibrating.

The second portion **22** of the electrode structure comprises a pair of end rings **23** and **24** having a plurality of wires **25** extending between them. The upper end ring **23** is substantially closed by the electrode **18**. The lower end ring **24** is provided with wires extending across the ring in a manner similar to that illustrated in Fig. 2 for the electrode **18**, so as to provide a closure at the lower end of the electrode structure **22**. Thus, the electrodes **18** and **22** define a field-free space of cylindrical shape.

By way of example, the rings **19**, **23**, and **24** may be composed of tungsten wire having a diameter of .030 inch. The wires **20**, **21** and **25** may be tungsten wires having a diameter of .002 inch, with the respective wires **20** and **25** being spaced ¼ inch apart. The wires which extend across the ring **24** may be tungsten wires having a diameter of .002 inch spaced ¼ inch apart. The .002 inch wire size and the ¼ inch spacing provide good results in the pumping apparatus of the present invention.

The large electrode structure 22 is supported by a plurality of shielded insulators 26 which are mounted on a stainless steel framework 28. Small tungsten wires 30 extend between the electrode structure and the insulators as the supporting members. The insulators comprise a portion of insulating material 32 surrounded by a copper jacket 33 which is crimped at its closed end 34 so as to secure the insulating material.

The upper electrode 18 is supported by a plurality of tungsten wires 35 which in turn are supported by insulators 36.

A thermionic filament 37 is located adjacent the electrode 18. The thermionic filament is distributed over a large area, as more clearly illustrated in Fig. 2, so as to distribute electrons throughout the space which is defined by the electrodes 18 and 22. The filament is supported by springs 38, and it is provided with an electric current at the terminals 39 and 40 from the secondary winding 41 of a transformer 42. The circuit interconnecting the secondary winding 41 and the terminals 39 and 40 is not shown in order to simplify the drawing.

I prefer to employ titanium as the gettering material, but other types of gettering materials may be employed if desired.

In the arrangement illustrated in Fig. 1, titanium wire is evaporated to provide the gettering action. The wire 44 is fed into the chamber from a housing 46 which is secured to the top of the chamber. The wire feed mechanism is insulated from the housing by the insulators 47. During operation of the pump, it is desirable that the getter be fed into the chamber at a substantially constant rate. It may be fed into the chamber by various mechanisms. One suitable mechanism is illustrated in the aforesaid copending patent application.

The gettering substance is evaporated from a post 48 which may be composed of graphite or any other suitable material. The evaporator post 48 is heated by a filament 50 which receives electric current from the secondary winding 52 of the transformer 42.

It is desirable to maintain the evaporator post 48 at a positive potential with respect to the evaporator filament 50 so that most of the electrons which are emitted by the evaporator filament will bombard the evaporator post and heat it. This may be achieved by a source of potential 53 coupled between the evaporator post and ground.

It is desirable to provide an optical system such as a window and one or more mirrors for observing the evaporator post so as to estimate its temperature before the gettering substance is applied to it. Such an optical system is not illustrated in order to simplify the present disclosure.

Preferably a reflector 54 circumscribes the evaporator post 48 so as to direct particles of getter material toward the interior wall of the chamber which is disposed adjacent the electrode 22. The reflector has a hole in its upper end so that the getter wire 44 may pass through the hole and contact the evaporator post 48. The reflector may be composed of molybdenum, for example.

The getter which impinges upon the reflector 54 may undergo a process better described as re-evaporation. The term reflector is used for convenience.

A plate 56 and a grid 58 provide an electrical shield between the evaporating apparatus and the remainder of the device so as to electrically isolate these two portions of the apparatus. By way of example, the plate 56 may be composed of copper or of stainless steel, and the isolation grid may be composed of tungsten wire. In the arrangement illustrated in the drawings, the plate 56 is supported by a plurality of conductive members 60 which are secured to the end plate 14 of the housing. Hence the plate 56 and the isolation grid 58 are at ground potential in this embodiment of the invention. It will be apparent that the plate 56 and the isolation grid 58 may be insulated from the housing if desired. In some instances it is desirable to bias the plate 56 and the isolation grid 58 negatively with respect to the ionization filament 37 so as to repel the electrons which the filament tends to direct upwardly.

Plates 61 and 62 may be mounted on insulators 63 between the plate 56 and end member 14 for supporting portions of the apparatus. Insulator supports 64 may be mounted on these plates for supporting the spring mounts for the ionization filament. The evaporating post 48 and the reflector 54 may be supported by arms 66 which in turn are supported by the plates 61 and 62.

A conduit 70 which spirals around the cylindrical portion 10 of the housing may carry a cooling fluid to cool the housing. In order to achieve maximum pumping speed, it is desirable to cool the surface on which the getter is located.

Also, it is desirable to provide a magnetic field which extends along the axis of the cylindrical member 10 in order to achieve maximum pumping speed. Such a magnetic field may be provided by the coil 72, which is provided with current from a source 73. The coil 72 may be wound in various manners. In a preferred arrangement the field at the center of the coil is made relatively weak compared to the fields at the ends of the coil. This may be achieved by using fewer turns at the center of the coil or by controlling the current going to various portions of the coil. It will be apparent that the housing should be composed of a nonmagnetic material if a magnetic field is to be employed. Nonmagnetic stainless steel may be employed if desired.

In order to provide the desired ionization action, the electrodes 18 and 22 are maintained at a positive potential with respect to the ionization filament 37 and also with respect to the wall of the housing member 10. The potentials for these anodes may be provided by sources of potential 76 and 78. In the arrangement illustrated in Fig. 1, the electrodes 18 and 22 are at the same potential. Thus, only one source of potential may be employed and the electrodes 18 and 22 may be connected to one another inside the chamber if desired.

It is desirable to maintain the ionization filament 37 at a positive potential with respect to the plate 56 and the isolation grid 58. This may be achieved by a source of potential 80 coupled between the transformer winding 41 and the housing.

It will be understood that the potentials which are illustrated for the sources 53, 76, 78 and 80 are merely illustrative and that various other potentials may be employed.

When the operation of the pump is initiated, it is usually desirable to reduce the pressure inside the chamber before the ionization and gettering actions of the pump are initiated. This may be done by the use of a forepump coupled to the valved port 16 and by evaporating gettering material from a primer 82. The primer comprises a plurality of conductors 84, such as tungsten wire having a diameter of .04 inch, disposed around a conductive hub 86. The hub 86 is supported by a conductive rod 88. Short pieces of getter material 90, such as titanium, are wound around the conductive rods, and this material may be evaporated by applying an electric current through the conductor on which the getter material is located. For example, if an electric current is applied through the terminals 92 and 94, the getter material on the upper conductor 84 may be evaporated.

By using several conductors to carry the getter material in the primer, the respective conductors may be heated at different times so as to minimize reloading the primer.

To initiate operation, the pressure is first reduced by the use of a suitable mechanical roughing pump coupled to the valved port 16. The two filaments may then be brought up to temperature, and the electric potentials may be applied to the evaporator post 48 and to the electrodes 18 and 22. Electric current is then applied to one of the conductors of the primer to evaporate the getter on the conductor. When the temperature of the evaporator

post 48 is sufficiently high to evaporate the getter, the wire feeder is actuated to feed the titanium wire onto the post at a substantially constant rate. The pump is then in operation.

In order to achieve high pumping speed, a fluid such as cool tap water should be circulated through the conduit 70 and current should be applied to the coil 72 so as to produce a magnetic field in the space which is enclosed by the electrodes 18 and 22.

The electrons which are emitted from the ionization filament 37 are drawn by the positive potential of the electrode 18 into the ionization space which is defined by the electrodes 18 and 22. The electrons which pass through the electrode 22 are drawn back into the space which is enclosed by the electrode 22 due to the positive potential of this electrode with respect to the interior walls of the chamber. Thus, the electrons tend to remain in the ionization space. The electrode structure has high transparency to electrons and hence most of the electrons are available for ionizing gas molecules. When gas molecules are bombarded by the electrons, they are ionized or dissociated by the impact, and then tend to drift toward the outer periphery of the chamber. The positive ions which move into the space between the anode 22 and the wall member 10 are driven by the positive potential of the anode 22 into the surface of the wall member 10 where they are collected. Deposition of the getter material provides an active surface along the wall of the member 10 for collecting gas molecules, and the continued deposition of the gettering material buries previously trapped gas molecules so that they can not escape.

If the coil 72 is energized so as to provide a magnetic field along the axis of the chamber, it tends to cause the electrons to have a spiral path when electrons move across the lines of magnetic flux. This increases the path of electron movement and hence enhances the ionization action.

The closed cylindrical electrode structure provides a large space for the ionization and dissociation of gas by electron bombardment, and the filament which is distributed over a large area serves to project electrons into substantially the entire space. Since the electrodes have high transparency to electrons, the electrons have a long path.

All the areas which are capable of absorbing electrons are either shielded from the ionizing region or they are made as small as possible. The plate 56 and the isolation grid 58 shield the ionizing region from the lead-in wires and the evaporator structure.

The portions 18 and 22 of the electrode structure which are disposed at an angle with respect to one another provide an effective arrangement for ionizing gas. The electrode 18 directs the electrons into the ionization space, and the electrode 22 serves to drive the ionized gas into the interior surface of wall 10 which collects the gas. Maximum ionization space is obtained by disposing the electrodes 18 and 22 approximately perpendicularly with respect to one another.

By using a reflector adjacent the evaporator post, the gettering substance may be directed to substantially the entire surface of the housing which is adjacent the electrode 22, thereby providing a large gettering surface composed of very small particles.

I claim:

1. A pumping device comprising a housing defining a chamber from which gas is to be removed, a collector surface disposed inside the housing for use in removing gas from the chamber, a source of electrons located in the chamber, electron-permeable electrode means defining a space in the chamber in which gas is to be ionized by electron bombardment, said electrode means having an end portion located adjacent the source of electrons for directing electrons into the ionization space and having a body portion disposed approximately perpendicularly with respect to said end portion and located adjacent the collector surface for driving the ionized gas to the collector surface, and means located in the chamber for evaporating a gettering substance in the chamber in a location to cause the evaporated getter to deposit on the collector surface.

2. The apparatus of claim 1 wherein the source of electrons is a thermionic filament located outside the ionization space which is defined by said electrode means.

3. The apparatus of claim 2 wherein the thermionic filament is distributed over a large area.

4. The apparatus of claim 1 further including a reflector located adjacent the evaporating means and disposed to direct the evaporated gettering substance toward the collector surface.

5. The apparatus of claim 1 wherein the evaporating means is located adjacent one end of said electrode means, and further including a reflector located adjacent the evaporating means and disposed to direct the evaporated gettering substance toward the collector surface.

6. The apparatus of claim 1 further including means for producing a magnetic field in the ionization space which is defined by said electrode means.

7. The apparatus of claim 1 wherein the chamber is provided with an inlet port which is disposed at the end of said electrode means which is opposite the end at which the source of electrons is located.

8. The apparatus of claim 1 further including means for cooling the collector surface so as to enhance the gettering action of the gettering substance which is deposited on the collector surface.

9. A pumping device comprising a housing defining a chamber from which gas is to be removed, a collector surface disposed inside the housing for use in removing gas from the chamber, a source of electrons located in the chamber, electron-permeable electrode means defining a space in the chamber in which gas is to be ionized by electron bombardment, said electrode means having a first portion located adjacent the source of electrons for directing electrons into the ionization space and having a second portion disposed at an angle with respect to the first portion and located adjacent the collector surface for driving the ionized gas to the collector surface, and means located in the chamber for evaporating a gettering substance in the chamber in a location to cause the evaporated getter to deposit on the collector surface.

10. A pumping device comprising a housing defining a chamber from which gas is to be removed, a collector surface disposed inside the housing for use in removing gas from the chamber, electron-permeable electrode means defining a space in the chamber in which gas is to be ionized by electron bombardment, a thermionic source of electrons located adjacent said electrode means and disposed externally of the space which is enclosed by said electrode means, said electrode means having a first portion located adjacent the source of electrons for directing electrons into the ionization space and having a second portion disposed at an angle with respect to the first portion and located adjacent the collector surface for driving the ionized gas to the collector surface, and means located in the chamber for evaporating a gettering substance in the chamber in a location to cause the evaporated getter to deposit on the collector surface.

11. A pumping device comprising a housing defining a chamber from which gas is to be removed, electrode means located in the chamber and defining a space which is substantially free of electric fields, means located in the chamber externally of the electrode means for projecting electrons into the field-free space to ionize the gas in the space, a collector surface located adjacent the electrode means, means coupled to the electrode means and the collector surface for maintaining the electrode means at a positive potential with respect to the collector surface so as to drive the ionized gas to the collector surface, and means located in the chamber for evap-

orating a gettering substance in a location to cause the evaporated getter to pass through a portion of the chamber and to be deposited on the collector surface, so that the getter traps the gas and secures it to the collector surface and also buries the gas previously deposited on the collector surface.

12. A pumping device comprising housing means defining a chamber from which gas is to be removed, a collector surface disposed inside the housing for use in removing gas from the chamber, first electrode means having an electron-permeable portion, a second electrode means having an electron-permeable portion located adjacent the collector surface and disposed approximately perpendicularly with respect to the first electrode means, a thermionic source of electrons located adjacent the first electrode means and externally of the space bounded by the first and second electrode means, means for maintaining the electrode means at a positive potential with respect to the source of electrons and with respect to the collector surface to drive the electrons from the source through the first portion of the electrode means and to drive positive ions into the collector surface, and means located in the chamber for evaporating a gettering substance in the chamber in a location to cause the evaporated getter to deposit on the collector surface, so that the getter traps the gas and secures it to the collector surface and also buries the gas previously deposited on the collector surface.

13. A pumping device comprising a housing defining a chamber of approximately cylindrical shape from which gas is to be removed, electron-permeable electrode means of substantially closed cylindrical shape located in the chamber with its cylindrical portion disposed adjacent the cylindrical wall of the housing, a source of electrons located at one end of the electrode means, and evaporating means located in the chamber for evaporating a gettering substance in a location to cause it to deposit on the interior walls of the chamber which are disposed adjacent said electrode means.

14. A pumping device comprising a housing having a cylindrical-shaped interior wall defining a chamber of approximately cylindrical shape from which gas is to be removed, electron-permeable electrode means of substantially closed cylindrical shape located in the chamber with its cylindrical portion disposed adjacent the cylindrical wall of the housing, evaporating means located at one end of the electrode means and disposed externally of the space which is defined by the electrode means for evaporating a gettering substance in a location to cause it to deposit on the interior walls of the chamber, a thermionic source of electrons located between the evaporating means and the adjacent end of said electrode means for directing electrons into the space which is defined by said electrode means, and electrical shielding means disposed between the evaporating means and the remainder of the device for providing electrical isolation therebetween.

15. A pumping device comprising a housing defining a chamber of approximately cylindrical shape from which gas is to be removed, electron-permeable electrode means defining a space in the chamber in which gas is to be ionized by electron bombardment, said electrode means being of substantially cylindrical shape and having its cylindrical portion disposed adjacent the cylindrical wall of the chamber, an inlet port for connecting the chamber to apparatus to be evacuated, with the inlet port being located at one end of said electrode means, a thermionic source of electrons located at the other end of said electrode means and disposed externally of the space which is enclosed by said electrode means, evaporating means for evaporating a gettering substance located approximately along the axis of the chamber and disposed externally of the space which is defined by said electrode means, and a reflector means circumscribing the evaporating means for reflecting the evaporated gettering substance to the wall of the chamber which is disposed adjacent said electrode means.

16. A pumping device comprising a housing having an interior wall of generally cylindrical shape defining a chamber of approximately cylindrical shape from which gas is to be removed, electron-permeable electrode means of substantially closed cylindrical shape located in the chamber with its cylindrical portion disposed adjacent the cylindrical wall of the housing, an inlet port for connecting the chamber to apparatus to be evacuated, with the inlet port being located at one end of said electrode means, a distributed source of electrons located at the other end of said electrode means and disposed externally of the space which is enclosed by said electrode means, evaporating means located approximately along the axis of the chamber and disposed externally of the space which is defined by said electrode means for evaporating a gettering substance, a reflector means circumscribing the evaporating means for reflecting the evaporated gettering substance to the interior wall of the housing which is disposed adjacent the electrode means, and means for producing a magnetic field extending along the cylindrical axis of the chamber.

17. The apparatus of claim 16 wherein the electron-permeable electrode means comprises wires having a diameter of the order of .002 inch spaced approximately .25 inch with respect to one another.

No references cited.