March 22, 1966 A. R. HAMILTON 3,241,740

VACUUM PUMPING METHODS AND APPARATUS

Filed Oct. 16, 1963 2 Sheets-Sheet 1

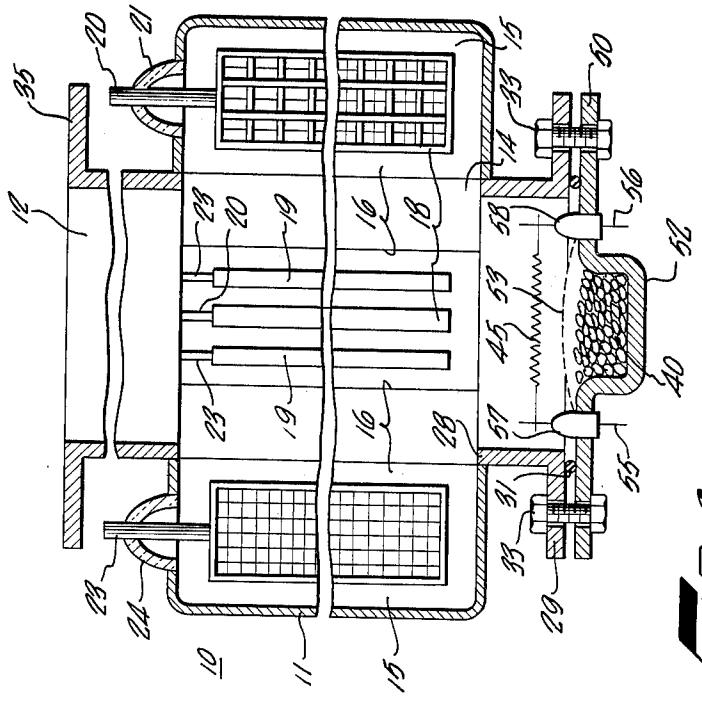


FIG. 2

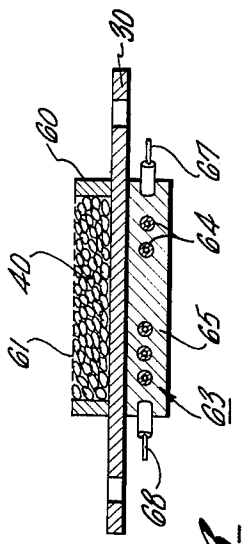


FIG. 3

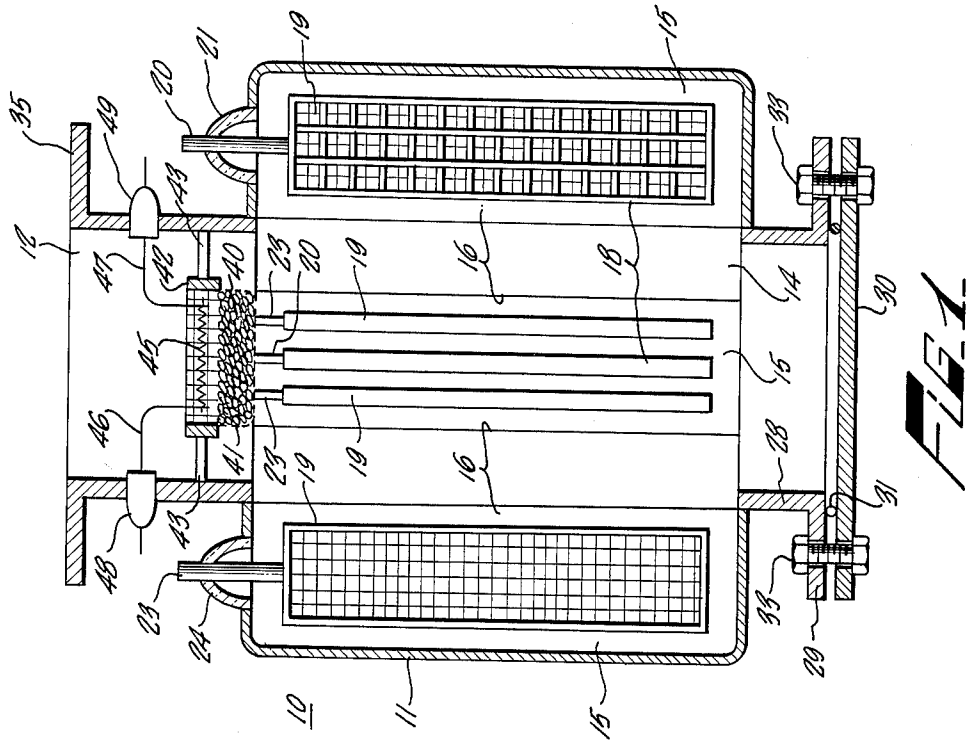


FIG. 1

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VACUUM PUMPING METHODS AND APPARATUS

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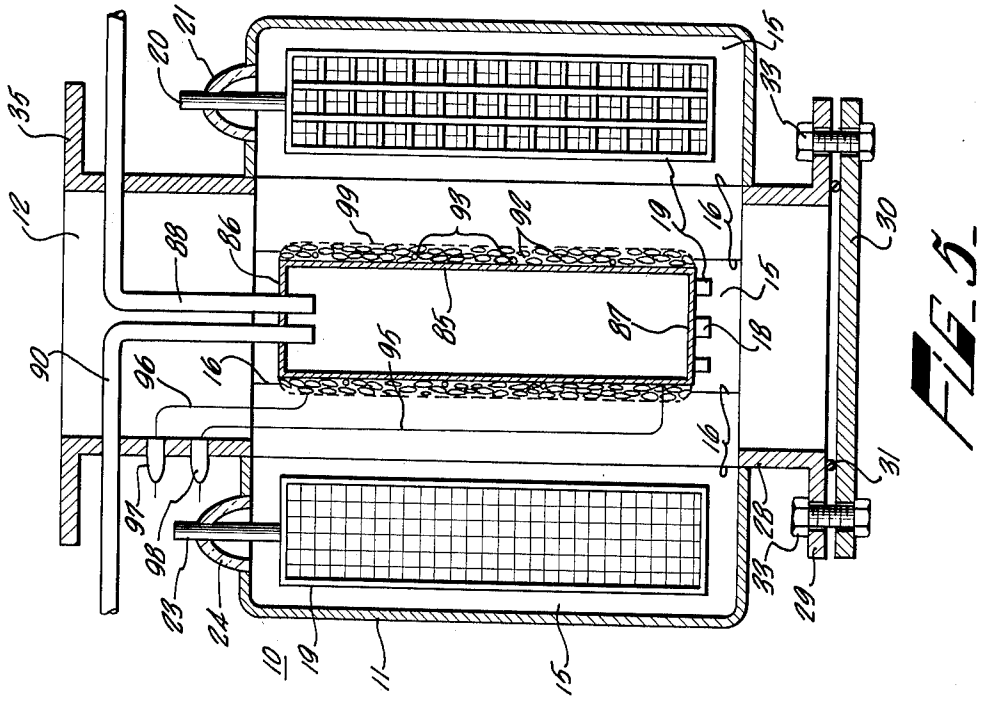


FIG. 3

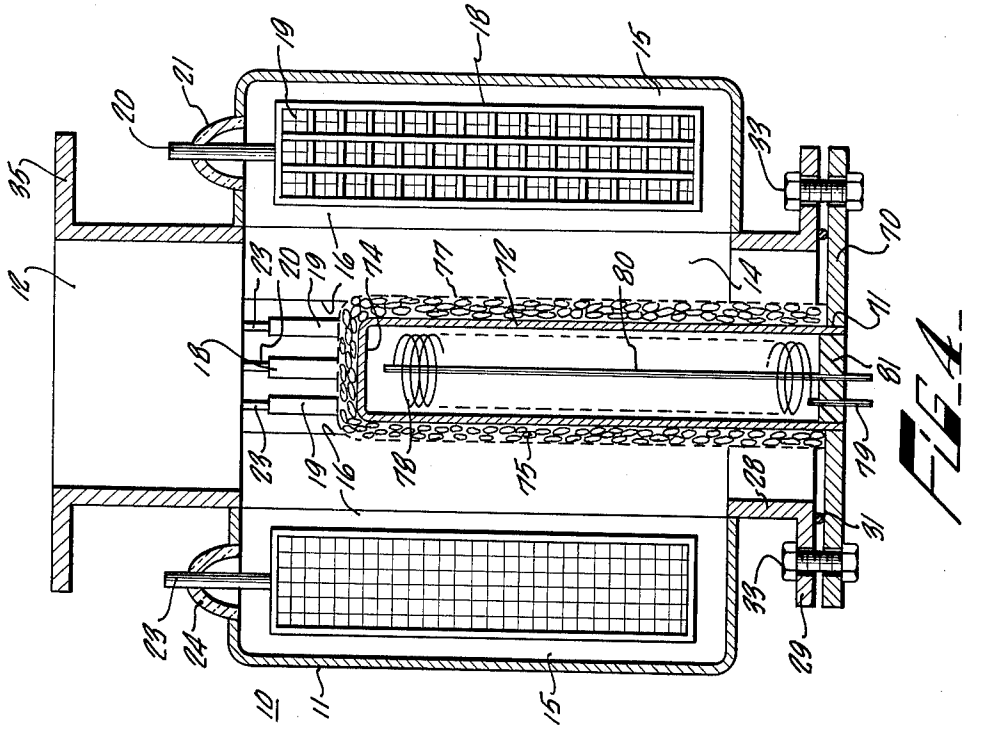


FIG. 4

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3,241,740

VACUUM PUMPING METHODS AND APPARATUS

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The subject invention relates to vacuum pumping methods and apparatus and, more particularly, to methods for improving the efficiency of cold cathode sputter ion vacuum pumps and to cold cathode sputter ion vacuum pump apparatus.

Cold cathode sputter ion vacuum pumps are well known in the art. They include a structure defining ion or gas molecule collector surfaces, at least one anode spaced from the collector surfaces, means for establishing an electric discharge in the space between the anode and the collector surfaces, and means for permeating the space between the anode and the collector surfaces with a magnetic field. During operation of this type of pump, the electric discharge releases electrons to the anode. These electrons strike and ionize gas molecules in the space between the sorption surfaces and the anode. The magnetic field serves to lengthen the path of these electrons and thus increases the probability that electrons will strike and ionize gas molecules. The ionized gas molecules deposit themselves on the collector surfaces. Some pumps include sputtering elements which release sputtered material upon impact by ions. The sputtered material is deposited on the collector surfaces and embeds the gas molecules collected thereon. Other pumps include a source of getter material for improving the collection and entrapment of gas molecules on the collector surfaces.

Pumps of this type are characterized by simplicity and generally effective operation. However, they have the tendency to outgas for a period of time when the pressure inside the pump is increased. This outgassing effect is believed to be due to the increased ion bombardment activity and the heating of the pump electrodes and casing which results from the higher power dissipation as the pressure is increased. As a result, the net speed of the pump decreases, often drastically, until ion bombardment outgassing equilibrium and temperature equilibrium have again been reached.

The invention compensates this outgassing effect by providing a supply of gas sorbent material in the pump. A preferred type of gas sorbent material is artificial zeolite, such as Linde 5A zeolite or Linde 13X zeolite. Other gas sorbent materials are activated alumina and activated coconut charcoal, for example.

The gas sorbent material enhances the action of the pump during the pumping cycle and particularly sorbes the gases that are released during the above-mentioned outgassing operation of the pump. In other words, pumping is performed by both the ion vacuum system and the gas sorbent material.

From time to time, it will be necessary to release sorbed gas from the sorbent material. According to the invention, this may be accomplished on systems which are periodically cycled from atmospheric pressure to very low pressure by maintaining the ion pump system in operation during periods of time between the pumping cycles. For example, the pump may be connected to the space to be evacuated by a high vacuum valve. After conclusion of a pumping cycle, the valve is closed and the ion pump system is maintained in operation so that sorbed gas is pumped from the gas sorbent material until the sorbent material is ready for the next pumping cycle. The sorbent material may also be outgassed by applying heat thereto, either while the ion pump system is in operation

between pumping cycles or while the pump is connected to a pre-evacuated space or to the atmosphere.

The sorbing action of the sorbent material may be improved by cooling this material during the pumping cycles. This may, for example, be accomplished by associating with the sorbent material a container or coil through which a coolant is circulated.

The vacuum pump of the invention comprises a pump housing, ion vacuum pump means inside the pump housing, and a supply of gas sorbent material in the pump housing.

The invention will be more readily apparent from the following detailed description of preferred embodiments thereof, illustrated by way of example in the accompanying drawings, in which:

FIG. 1 is an elevation, in section, of a first embodiment of the vacuum pump according to the invention;

FIG. 2 is an elevation, in section, of a second embodiment of the vacuum pump according to the invention;

FIG. 3 illustrates a modification of the pump shown in FIG. 2;

FIG. 4 is an elevation, in section, of a third embodiment of the vacuum pump according to the invention; and

FIG. 5 is an elevation, in section, of a fourth embodiment of the vacuum pump according to the invention.

In the various drawings, like reference numerals are employed for like parts.

The pump **10** shown in the drawings is of the well known type that has a housing **11** which defines a pump inlet **12**, a central chamber **14** communicating with the inlet **12**, and a plurality of pump chambers **15** issuing into central chamber **14**. Each pump chamber **15** defines a pair of molecule ion collector surfaces **16** and contains a cellular anode **18** and a pair of cellular sputter electrodes **19**. In the left-hand pump chamber of pump **10**, the anode **18** has not been shown to permit a full view of one of the sputter electrodes **19**. Each of the anodes **18** has a terminal **20** which extends through a bushing **21** to the outside of housing **11**. Similarly, each sputter electrode **19** has a terminal **23** which extends through a bushing **24** to the outside of housing **11**. The illustrated pump **10** actually has four pump chambers, one of these being not apparent from the illustrated section through the pump. The pump also has the conventional magnets (not shown) between the pump chambers **15** for establishing magnetic fields through these pump chambers.

Each of the pumps shown in the drawings has a lower tubular nipple **28** which communicates with the central chamber **14** and which has an outer flange **29**. In the pump shown in FIG. 1, as well as in the pump shown in FIG. 5, the tubular nipple **28** is closed by a plate **30** which extends to the periphery of flange **29**, and by a sealing ring **31** which is interposed between flange **29** and plate **30**. Nut and bolt assemblies **33** releasably connect plate **30** to flange **29**.

During operation, the pump inlet **12** is connected to the space to be evacuated (not shown). A flange **35** at inlet **12** facilitates this connection. The vacuum space is first pre-evacuated by a conventional roughing pump (not shown) in a conventional manner. A positive high voltage potential is then applied to anodes **18** and a negative potential to sputter electrodes **19**. The housing **11** with collector surfaces **16** may be grounded. The resulting electrons which travel to anodes **18** will strike and ionize gas molecules present in the pump chambers **15**. The magnetic fields in these chambers will cause the electrons to travel along helical paths and will thus cause an increased ionization of gas molecules. The ionized gas molecules will travel to ion collector surfaces **16**. Some of the ionized gas molecules will strike the sputter electrodes **19** and will release sputter material particles onto collector surfaces **16**. These particles will embed the ions

on the collector surfaces **16** and provide fresh surfaces for chemical gettering of active gas molecules.

The pump operation and the pump structure so far described in connection with the drawings are well known in the art. Some of the known pumps of the subject type also include a source of getter material (not shown) for assisting the above-described gas molecule pumping process.

The pumps so far described have the disadvantage of displaying outgassing effects during the pumping operation, as has been stated above. This disadvantage is overcome in the pumps shown in the drawings in various ways.

According to FIG. 1, the pump **10** has a supply **40** of sorbent material, such as artificial zeolite, disposed in pump inlet **12**. This sorbent material is in granular form and is held in a basket **41** of wire mesh. The basket **41** is mounted by an annulus **42** which, in turn, is positioned and held in inlet **12** by mounting rods **43**. A radiant heater **45** is mounted above supply **40** by a pair of terminal rods **46** and **47**. Terminal rods **46** and **47** extend through bushings **48** and **49** to the outside of housing **11**. Whenever it is desired to release sorbed gas from the sorbent material of supply **40**, the terminal rods **46** and **47** are connected to an electric power supply (not shown). This causes heater **45** to radiate heat and thus to increase the temperature of the sorbent material. With increased temperature, the sorbent material will release previously sorbed gas therefrom. This degassing process of the sorbent material may be carried out while the pump inlet **12** is open to the atmosphere or, preferably, while the pump inlet is connected to a roughing pump (not shown). Alternatively, this degassing process may also be carried out while the pump inlet valve is closed and the ion pump systems in the pump chambers **16** are operated. This degassing process can thus be carried on during periods of time in which the pump is not used for evacuation processes.

During the pumping operation, the heater **45** is de-energized and the sorbent material in supply **40** will assist the ion pump systems in performing their pumping operation, particularly during those periods of time in which the elements of the ion pump systems display the above-mentioned outgassing effect. In this manner, the operation of the pump is significantly improved.

In the pump shown in FIG. 2, the supply **40** of sorbent material is located at the bottom of the pump. To this effect, the plate **30** shown in FIG. 1 is replaced by a disc **50** which defines a pan **52**. The supply **40** is located in pan **52** and is retained therein by a piece of wire mesh **53**. The above-mentioned radiant heater **45** is mounted above supply **40** by a pair of terminal rods **55** and **56**, which extend through bushings **57** and **58** to the outside of disc **50**. The heater **45** is selectively energized by connecting the terminal rods **55** and **56** to an electric power source (not shown). The operation of heater **45** and sorbent material supply **40** is the same as that of the like parts in FIG. 1.

FIG. 3 shows a modification of the embodiment shown in FIG. 2. According to FIG. 3, the above-mentioned plate **30** has an annulus **60** mounted on the upper surface thereof. The supply **40** of sorbent material is disposed in annulus **60** and is retained therein by a piece of wire mesh **61**. Instead of the radiant heater **45**, the embodiment shown in FIG. 3 employs a heater **63** which is attached to the lower surface of plate **30**. Heater **63** comprises turns of a heater element **64** embedded in a disc **65** of heat conducting material, such as aluminum. The heater element **64** has terminals **67** and **68** which are connected to an electric power source (not shown) when it is desired to heat sorbent material supply **40** and to release sorbed gas therefrom. The plate **30** with the associated parts shown in FIG. 3 is connected to the pump shown in FIG. 2 in lieu of the disc **50**. When the embodiment shown in FIG. 3 is used, heat is supplied to the granulated sorbent material principally by heat conduction rather than radiation. The function of supply **40** in FIG. 3 is the same as that of the supply of sorbent material in FIG. 2.

The embodiments shown in FIGS. 2 and 3 have the advantage over the embodiment of FIG. 1 that the supply of sorbent material does not constitute a molecule flow impedance in the pump inlet. However, in the embodiment shown in FIG. 1 the sorbent material is positioned more readily in the paths of the gas molecules than in the embodiments illustrated in FIGS. 2 and 3.

FIG. 4 shows an embodiment in which the sorbent material is disposed in the general area where gas molecules are present, but in which a gas flow impedance in pump inlet **12** is avoided. In the embodiment shown in FIG. 4, the above-mentioned plate **30** is replaced by a plate **70** which has a central aperture **71**. A tube **72** is mounted on plate **70** and has one end thereof extending through aperture **71**. A vacuum tight seal is established between tube **72** and plate **70**, such as by welding. The tube **72** has a closed free end **74**. Granular sorbent material **75**, such as artificial zeolite, is distributed over the outside surface of tube **72** and is retained thereon by wire mesh **77**. If desired, the granular material **75** may also be held on tube **72** by a suitable adhesive, such as an epoxy cement, Teflon cement or an adhesive silicon compound.

A heater **78** is mounted in tube **72** by a pair of terminal rods **79** and **80** which extend through a disc **81**. The disc **81** is of a suitable insulating material, such as a ceramic, and is fitted and mounted in tube **72** at the lower end thereof. The heater **78** is energized by connecting terminal rods **79** and **80** to an electric power source (not shown) when it is desired to heat the sorbent material **75** and to expel sorbed gas therefrom.

During the operation of the pump shown in FIG. 4, the heater is disconnected from its power source, and the sorbent material **75** will assist the ion pump systems in the manner described above. The sorbent material **75** will be very effective in performing its function since it extends a large portion of the central chamber **14** in pump **10**.

In the embodiment shown in FIG. 5, a tube **85** is disposed in central chamber **14**. Tube **85** has closed ends **86** and **87**. A first pipe **88** extends from the outside of housing **11** to tube **85** and through the closed end **86** of the tube. The pipe **88** terminates inside tube **85** shortly below the closed end **86** thereof. A second pipe **90** extends from the inside of tube **85**, through closed tube end **86** and to the outside of housing **11**. Pipe **88** is an inlet pipe for supplying a coolant to the inside of tube **85**, and pipe **90** is an outlet pipe for evaporated coolant from tube **85**. The function of the coolant will be subsequently described.

Granulated sorbent material **92**, such as artificial zeolite, is distributed over the outer surface of tube **85**. A coil of resistance wire **93** extends also along the outer surface of tube **85**. The resistance wire **93** has an electrically insulating oxide coating and forms a heater on tube **85**. A pair of terminal rods **95** and **96** are connected to resistance wire **93** and extend through bushings **97** and **98** to the outside of the housing **11**. A wire mesh screen **99** holds the granular sorbent material **92** against tube **85**.

The heater terminals **95** and **96** are connected to an electric power source (not shown) when it is desired to energize the resistance wire **93** and to expel sorbed gas from the sorbent material **92** in the manner mentioned above. During the vacuum pumping operation, the resistance wire **93** is de-energized and a suitable coolant, such as liquid nitrogen, is introduced into the tube **85**. The coolant will lower the temperature of the sorbent material **92** and will thus enhance its gas sorbing action. Gaseous nitrogen will escape through outlet pipe **90**.

Upon completion of the vacuum pumping operation, the supply of coolant to tube **85** is interrupted. Sorbed

gas may then be expelled from the sorbent material by energization of resistance wire **93**.

It will be recognized that the pump shown in FIG. 5 embodies also a very effective means for assisting the ion pumping system in the manner mentioned above.

While preferred embodiments of the invention have been shown herein, it will be apparent that many modifications thereof within the scope of the invention are possible. Thus, the invention may be employed with pump systems other than those illustrated in the drawings. For example, the invention may also be employed with ion pumps that have only one pump chamber. Moreover, the over-all configuration of the supply of sorbent material may be conical rather than cylindrical. Other modifications within the scope of the invention will be apparent to those skilled in the art.

I claim:

1. A vacuum pump comprising:
(a) a pump housing;
(b) ion vacuum pump means inside the pump housing; and
(c) a receptacle inside the pump housing, the inside of the receptacle communicating with the inside of the pump housing; and
(d) a supply of granules of gas sorbent material in said receptacle.

2. A vacuum pump comprising:
(a) a pump housing;
(b) ion vacuum pump means inside the pump housing;
(c) a receptacle inside the pump housing, the inside of the receptacle communicating with the inside of the pump housing;
(d) a supply of granules of gas sorbent material in said receptacle; and
(e) heater means adjacent said supply for periodically heating and outgassing the sorbent material.

3. A vacuum pump comprising:
(a) a pump housing;
(b) ion vacuum pump means inside the pump housing;
(c) a receptacle inside the pump housing, the inside of the receptacle communicating with the inside of the pump housing;
(d) a supply of granules of gas sorbent material in said receptacle; and
(e) cooling means adjacent said supply for periodically lowering the temperature of the sorbent material.

4. A vacuum pump comprising:
(a) a pump housing;
(b) ion vacuum pump means inside the pump housing,
(c) a supply of gas sorbent material in the pump housing;
(d) heater means adjacent said supply for periodically heating and outgassing the sorbent material; and
(e) cooling means adjacent said supply for selectively lowering the temperature of the sorbent material.

5. A vacuum pump comprising:
(a) a housing defining a pump inlet and a pump chamber;
(b) ion vacuum pump means inside the pump chamber;
(c) a supply of gas sorbent material in the pump inlet; and
(d) heater means adjacent said supply for periodically heating and outgassing the sorbent material.

6. A vacuum pump comprising:
(a) a housing defining a pump inlet and a pump chamber;
(b) ion vacuum pump means inside the pump chamber;
(c) a supply of gas sorbent material in the pump inlet; and
(d) heater means in the pump inlet for periodically heating and outgassing the sorbent material.

7. A vacuum pump comprising:
(a) a housing defining a bottom, a pump inlet and a pump chamber between the bottom and the inlet;
(b) ion vacuum pump means in the pump chamber; and
(c) a supply of gas sorbent material inside the housing and at the bottom thereof.

8. A vacuum pump comprising:
(a) a housing defining a bottom, a pump inlet, and a pump chamber between the bottom and the inlet;
(b) ion vacuum pump means in the pump chamber;
(c) a supply of gas sorbent material inside the housing and at the bottom thereof; and
(d) heater means adjacent said supply for periodically heating and outgassing the sorbent material.

9. A vacuum pump comprising:
(a) a housing defining a bottom, a pump inlet, and a pump chamber between the bottom and the inlet;
(b) ion vacuum pump means in the pump chamber;
(c) a supply of gas sorbent material inside the housing and at the bottom thereof; and
(d) a radiant heater in the housing and above said supply for periodically heating and outgassing the sorbent material.

10. A vacuum pump comprising:
(a) a housing defining a bottom, a pump inlet, and a pump chamber between the bottom and the inlet;
(b) ion vacuum pump means in the pump chamber;
(c) a supply of gas sorbent material inside the housing and at the bottom thereof; and
(d) a heater on the bottom of the housing for periodically heating and outgassing the sorbent material.

11. A vacuum pump comprising:
(a) a housing defining a pump inlet, a central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;
(b) ion vacuum pump means in the pump chambers; and
(c) a supply of gas sorbent material in the central chamber.

12. A vacuum pump comprising:
(a) a housing defining a pump inlet, a central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;
(b) ion vacuum pump means in the pump chambers;
(c) a supply of gas sorbent material in the central chamber; and
(d) heater means adjacent said supply for periodically heating and outgassing the sorbent material.

13. A vacuum pump comprising:
(a) a housing defining a pump inlet, a central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;
(b) ion vacuum pump means in the pump chambers;
(c) a supply of gas sorbent material in the central chamber; and
(d) cooling means adjacent said supply for periodically lowering the temperature of the sorbent material.

14. A vacuum pump comprising:
(a) a housing defining a pump inlet, a central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;
(b) ion vacuum pump means in the pump chambers;
(c) a supply of gas sorbent material in the central chamber;
(d) heater means adjacent said supply for periodically heating and outgassing the sorbent material; and
(e) cooling means adjacent said supply for selectively lowering the temperature of the gas sorbent material.

15. A vacuum pump comprising:
(a) a housing defining a pump inlet, an elongated central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;
(b) ion vacuum pump means in the pump chambers;

(c) a closed tubular member in the elongated central chamber; and

(d) a supply of gas sorbent material distributed over the outside of the tubular member in the central chamber.

16. A vacuum pump comprising:

(a) a housing defining a pump inlet, an elongated central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;

(b) ion vacuum pump means in the pump chambers;

(c) a closed tubular member in the elongated central chamber;

(d) a supply of gas sorbent material distributed over the outside of the tubular member in the central chamber; and

(e) heater means inside the tubular member for periodically heating and outgassing the sorbent material.

17. A vacuum pump comprising:

(a) a housing defining a pump inlet, an elongated central chamber communicating with the pump inlet, and pump chambers opening into the central chamber;

(b) ion vacuum pump means in the pump chambers;

(c) a closed tubular member in the elongated central chamber;

(d) a supply of gas sorbent material distributed over the outside of the tubular member in the central chamber;

(e) heater means adjacent the tubular member for periodically heating and outgassing the sorbent material; and

(f) means for selectively introducing a coolant into the closed tubular member for lowering the temperature of the sorbent material.

18. A method of improving the efficiency of a vacuum pump having an ion vacuum pump system, comprising the steps of:

(a) providing a supply of gas sorbent material in the pump for enhancing the pumping action during the pumping cycles; and

(b) operating the ion vacuum pump system between pumping cycles for removing sorbed gas from the sorbent material.

19. A method of improving the efficiency of a vacuum pump having an ion vacuum pump system, comprising the steps of:

(a) providing a supply of gas sorbent material in the pump for enhancing the pumping action during the pumping cycles; and

(b) heating the gas sorbent material between pumping cycles for removing sorbed gas therefrom.

20. A method of improving the efficiency of a vacuum pump having an ion vacuum pump system, comprising the steps of:

(a) providing a supply of gas sorbent material in the pump;

(b) cooling the supply of gas sorbent material during the pumping cycles of the pump; and

(c) heating the supply of gas sorbent material between pumping cycles for removing sorbed gas therefrom.

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