Jan. 7, 1964 R. L. JEPSEN 3,117,247

VACUUM PUMP

Filed May 29, 1961

FIG.1

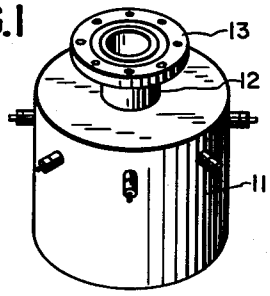


FIG.4

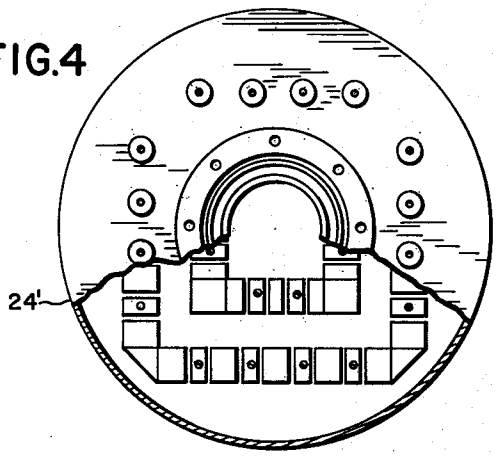


FIG.2

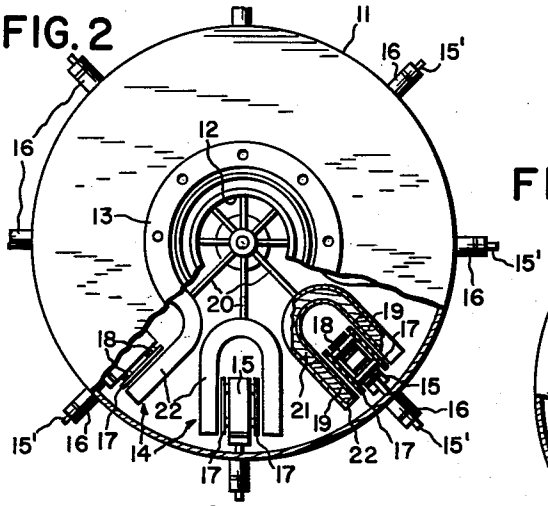


FIG.5

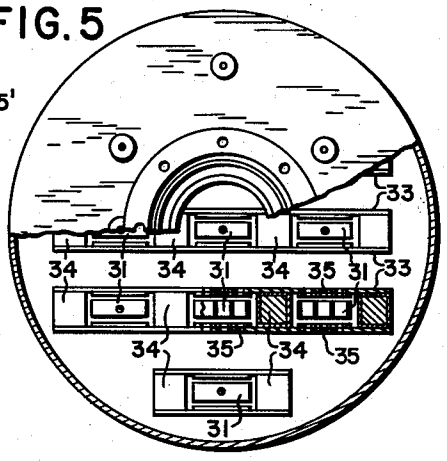


FIG.3

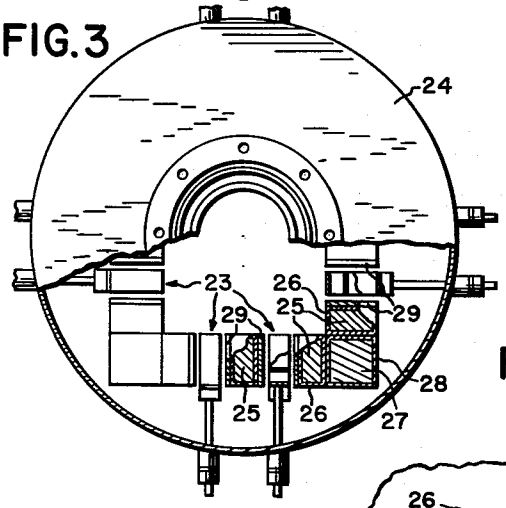


FIG.7

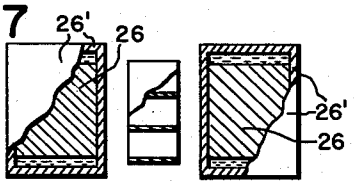


FIG.8

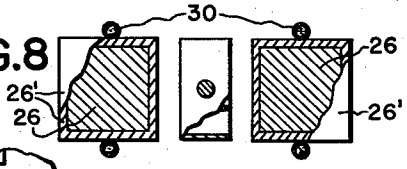
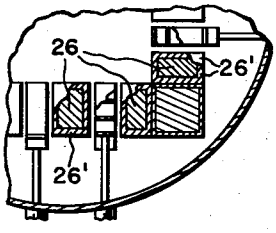


FIG.6



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VACUUM PUMP

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The present invention relates, in general, to vacuum pumps and gauges and, more particularly, to a novel sputter ion pump and gauge apparatus.

Heretofore certain electrical vacuum pumps, termed sputter ion pumps, have been built utilizing a cold cathode gas discharge wherein the glow discharge is established in multiple paths within an open-ended, multicellular anode disposed between and spaced from two cathode plates, a magnetic field being provided through the anode to cause the electrons in the glow discharge to travel in long spiral paths. Positive ions produced by the glow discharge are directed by electrical potentials against the cathode plates and the ions impinging on the cathode plates produce sputtering of a reactive cathode material. The sputtered material is collected upon the interior surfaces of the pump where it serves to entrap molecules in the gaseous state coming in contact therewith. Also, a certain amount of diffusion of gases into the cathode occurs, especially with hydrogen. In this manner, the gas pressure within the pump envelope enclosing the cathode and anode elements is reduced. Since the ion current is a linear function of the gas pressure, the above device also serves as a vacuum gauge.

In general, these vacuum pumps have taken the form of a pump envelope within which the cathode plates and the anode are positioned, the envelope having a port which serves to connect the pump to the system to be evacuated. The magnet has generally taken the form of a steel magnet such as alnico or a ceramic ferrite magnet such as Indox, the magnet being located outside the envelope of the vacuum pump and positioned so as to direct its magnetic field through the cathode plates and cellular anode. This had led, in the case of larger pumps with large anode-cathode areas, to complex convolute envelope shapes which will accommodate the necessary number of external magnets.

In other instances it has been found desirable to place the anode-cathode elements directly within the vessel or enclosure which one is seeking to evacuate and, where such vessel already contains a magnetic field used for other purposes, the pump elements have been placed so as to utilize such magnetic field. In those instances where no magnetic field is already available, magnets have been placed outside the vessel as in the case of standard pump designs.

It is recognized in some instances of use that it would be preferable in the case of vessels which do not already contain a convenient magnetic field to produce the necessary magnetic field, to place the magnets within the vessel to be evacuated so as to space the magnets as close to the anode-cathode elements as possible. It is also recognized that in the case of the construction of large pumps it would be preferable to place the magnets within the vacuum pump envelope thus avoiding the use of complex convolute pump envelopes necessary to accommodate external magnets. However, such magnets are made of very poor vacuum material, i.e., porous and dirty, and such magnets have therefore a very deleterious effect on the operation of the pump. The burden on the pumping system is increased since it must now also pump gases out of the porous magnet material.

In accordance with the present invention, the magnets for producing the magnetic field through the cathode-anode structure are placed first within a vacuum tight

envelope or can and the canned magnet then positioned within the vessel to be evacuated or within the vacuum pump envelope, the magnet thus being sealed off from the pumping area and thus avoiding the above noted deleterious effects.

It is, therefore, the object of the present invention to provide a novel improved magnet structure, for use, for example, in a cold cathode discharge vacuum pump or gauge for producing the magnetic field through the anode-cathode elements wherein the magnet structure may be contained within the vacuum envelope of the vessel being evacuated or the pump or gauge.

One feature of the present invention is the provision of a novel magnet structure, for use, for example, in a vacuum pump or gauge apparatus in which the magnet structure is utilized to supply the magnetic field through the sputter ion device, wherein the magnets are sealed within a vacuum envelope or can prior to insertion of the canned magnet within the vacuum envelope.

Another feature of the present invention is the provision of a sputter ion apparatus wherein the magnet producing the magnetic field through the device is vacuum sealed within a can or envelope of getter material, the magnet can or envelope providing the dual function of isolating the magnet from the vacuum system and serving as the cathode for the sputter ion device.

Another feature of the present invention is the provision of a "canned magnet" sputter ion vacuum device of the above featured type wherein means are provided for cooling the can and magnet.

Still another feature of the present invention is the provision of a sputter ion apparatus of the above featured types wherein the can or magnet envelope is partially evacuated to reduce the rate at which gas from within the can will flow into the pump through a leak in the can if one should occur.

Still another feature of the present invention is the provision of a "canned magnet" for use in a sputter ion device of the immediately above featured type wherein the can also contains a gas which may be readily detected, such as helium, so that a leak detector utilized outside of the vessel to be evacuated or the vacuum pump or gauge envelope may detect the presence of a possible leak in the can within the vessel or envelope.

Another feature of the present invention is the provision of a "canned magnet" sputter ion device wherein the can is of thin metal of good vacuum material such as stainless steel surrounding the magnet, the magnet serving to support the walls of the thin walled evacuated can.

These and other features and advantages of the present invention will become apparent upon a perusal of the following specification taken in connection with the accompanying drawings wherein,

FIG. 1 is an isometric view of a vacuum pump embodying the present invention,

FIG. 2 is a plan view of the pump shown in FIG. 1 partially broken away to show the anode and cathode members of the getter ion pump elements and also the canned magnets associated with these elements,

FIG. 3 is a plan view partially broken away and partially in cross section showing another embodiment of the present invention wherein the pump elements are arranged in the form of a square,

FIG. 4 shows still another embodiment of the present invention wherein the pump elements are arranged in concentric manner,

FIG. 5 shows still another embodiment of the present invention,

FIG. 6 shows a partial view of still another embodiment of the invention wherein the magnet can also serves as a cathode, and

FIGS. 7 and 8 show two possible forms of cooling of

the canned magnets utilized in the embodiments of the present invention.

Referring now to FIGS. 1 and 2 there is shown a vacuum pump comprising an outer envelope 11 communicating with a hollow tubular extension 12 having a flange 13 thereon which serves to connect this pump to the system to be evacuated. A plurality of individual pump units 14 are positioned in a radial arrangement within the pump envelope 11. Each pump unit comprises a multicellular anode 15 which is supported on the pump envelope by means of an insulator 16. Spaced from the open ends of the cells in the anode 15 are a pair of cathode plates 17 which may be mounted by means of insulators 18 on the anode cell structure 15 or in other manners as desired. The cathode plates 17 and cellular anode 15 are located in the gap spacing between two soft iron pole pieces 19 which are secured to the ends of a horseshoe shaped magnet 21 made of magnetic material such as, for example, steel or Alinico V. The magnet 21 and the pole pieces 19 are vacuum sealed within a horseshoe shaped can or envelope 22 made of a good vacuum material such as stainless steel. The canned magnets are secured to the base plate of the pump envelope 11 by a spoke mount means 20. Regarding the cathode mounting, the cathodes could be mounted directly on the outer surface of the canned magnet; the anodes could also be mounted by means of insulators on the cathodes and magnets.

In typical operation of this vacuum pump, a positive potential of .4 to 10 kilovolts or more is applied to the anode members 15 by way of the insulator conductor rods 15'. The vacuum envelope 11 and the cathode plates 17 are preferably operated at ground potential to reduce hazard to operating personnel. The applied potentials produce a region of intense electric field between the cellular anode 15 and the cathode plates 17. This electric field, acting in combination with the magnetic field produced across the pole pieces 19, produces a breakdown of gas within the anode region resulting in a glow discharge within the cells of the anode 15 between the cathode plates 17. This glow discharge results in positive ions being driven into the cathode plates 17 to produce sputtering of reactive cathode material onto the nearby pump elements including the anode to produce gettering of molecules and ions in the gaseous state coming in contact with this sputtered material. In this manner, the pressure within the vacuum envelope and, therefore, structures communicating therewith through the tubular extension 12, is lowered. It should be noted that the cathode-anode and magnet elements described above could also be placed directly in the vessel one desired to evacuate.

Referring now to FIG. 3 there is shown another embodiment of the present invention wherein a plurality of pumping units 23 are arranged in a square configuration within a hollow cylindrical vacuum pump envelope 24. In this case the magnets 25 are of a ceramic type located within vacuum tight cans 26. Soft iron pieces 27 located in vacuum tight cans 28 are utilized in the corner positions to facilitate the flux flow between the end magnets. The cathodes 29 are mounted directly on the cans.

In the pump embodiment shown in FIG. 4 a larger plurality of pump elements and associated magnets similar to those shown in FIG. 3 are arranged in a concentric manner to provide optimum conductance characteristics. The pump anode elements are mounted by means of insulators extending through the end wall of the cylindrical vacuum envelope.

Because the pole pieces 19, the permanent magnets 21 and 25 and the corner pieces 27 in the above embodiments are vacuum sealed within the cans or shells 22, 26 and 28, they are isolated from the pumping areas and there is no necessity for even partially removing the gas contained within these magnet pieces although it may be desirable for the following reasons.

In the use of such canned magnets it is desirable that the can surrounding the magnet be of quite thin material to insure that little of the magnet gap is used up by the can material resulting in more efficient utilization of the magnet material. With the can unevacuated, it would tend to bulge outwardly when the pumping area is evacuated. However, sealing the cans off at a reduced pressure (such as 1 mm. of Hg or less) causes the can to press against the magnets for support, substantially reduces the tendency of the can to bulge out when the pumping area is evacuated and also substantially reduces the rate at which gas will flow out through any leaks in the can should one occur.

Leak detection after seal-off of the magnet cans may be facilitated by enclosing in the can a convenient gas such as helium. A conventional helium leak detector may then be utilized to test for leaks in the magnet can. This leak detection method may also be employed when the canned magnets are within the vacuum system or pump since helium leaking from any of the cans within the system will also be detected as a helium gas leak at a convenient access point in the vacuum envelope of the system or pump.

It is noted that the envelopes 11, 24 and 24' of the above pumps are very simple in shape, that is, a hollow cylindrical form. This simple shape results from the fact that the magnets may be placed within the vacuum envelope in any desired arrangement without undue concern regarding the envelope. It is also noted that canning of the magnets permits the placement of magnets and anode-cathode structures at points within the pump envelope which will produce improved gas access to the anode region. In particular, gas access is obtained on two sides instead of one,, as is usually the case in standard pumps.

Also, in getter ion pumps heretofore used wherein the magnets are located outside of the complex convolute vacuum envelopes, there is an optimum length-to-diameter ratio of the pump envelope to produce the most desired pumping results. Upon placing the pumping elements concentrically as shown in FIG. 4, the optimum length-to-diameter ratio would be reduced (i.e., pump becomes somewhat shorter) and therefore is more conveniently adapted to fit within prescribed system dimensions.

An additional advantage of such a system is the fact that there are less conductance limitations since the pump elements and magnets can be arranged about inside of a vacuum chamber at will and therefore high pumping speeds may be realized for a given size pump element. In addition, when these canned magnets and pump elements are placed bodily within the system envelope one desires to evacuate, it is not necessary to supply a separate vacuum envelope for the pump elements nor to provide a connection to the system envelope being pumped from an attached vacuum pump envelope.

A further embodiment is shown in FIG. 5 in which the pump elements employ a more efficient utilization of magnetic material. In this case the cellular anode structures 31 are positioned between the two cathodes 32 and this anode-cathode structure is in turn mounted between two flat soft iron pole pieces 33 which are mounted at spaced points on canned ceramic magnets 34. Gas access to the anode region is provided by holes or slots 35 cut through the soft iron pole pieces and cathodes 32. The slots or holes in the cathodes are located at points which are least apt to be bombarded by the positive ions. This particular pump arrangement is rendered feasible and practical only through the use of canned magnets.

In many instances utilizing canned magnets, the magnet cans may be conveniently made of the desired getter material such as titanium and these cans will themselves serve as the cathodes for the sputtering of getter material. Since the canned magnets can be readily removed from the pump envelopes, element replaceability is retained in that, when the magnet cans are "worn out," new cans may be placed on the magnets thus permitting the mag-

nets to be reused. Should the magnet cans also serve as the pump cathodes, it then becomes desirable to use relatively thick-walled material, for example, .1 inch. In this situation evacuation of the interior of the magnet can is not as necessary as in the case of thin-walled cans since the thick-walled cans will have less tendency to bulge out when the pump is evacuated. There is no problem with magnet-cathode gap spacing in such cases since the cathode can abuts the magnet material. A portion of a pump similar to that shown in FIG. 3 is depicted in FIG. 6, in which the magnet can 26' serves as the cathode.

In the case of certain getter ion pump applications it is desirable to cool the pump elements, for example, the cathode, and this may be conveniently accomplished by flowing a coolant liquid such as air or water through a fluid conduit 30 secured to the edges of the cans as shown in FIG. 8. Such fluid conduits may be coupled to either the thin wall canned magnets of the type shown in FIGS. 2 or 3 or the thicker walled cathode cans shown in FIG. 6. In the case of the thick-walled cathode cans, the cans may be made wider than the magnets to provide a flow space on either side of the magnet to permit the coolant fluid to flow directly within the can from outside of the vacuum envelope, as shown in FIG. 7.

It is well known in the art that the sputter ion pump also may serve as a vacuum gauge because the ion current is a function of the gas pressure; therefore this invention applies with equal force to such devices utilized as gauges.

Another advantage in using canned ferrite magnets arises in high temperature applications. At present large ferrite magnets are made by cementing smaller pieces together. Upon heating above some critical temperature, for example, 150° C. in the case of certain ferrites, the cement softens. In the case of canned magnets as presently proposed, magnets need not be cemented since the can will hold the magnet pieces together. Even if the pieces are cemented together, the can will hold the pieces together even when the cement softens above the particular temperature.

Also, it may be convenient and desirable to work with unmagnetized blocks of ferrite during assembly and welding. The ferrites can then be magnetized in the can, the can providing a suitable holder for the magnet pieces.

This invention is also applicable to other instances of use in which the insertion of a magnet material within a vacuum envelope to be subsequently evacuated is desirable or necessary.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electrical vacuum apparatus utilizing the principle of particle bombardment of a cathode structure including, in combination, an anode structure having a plurality of glow discharge passageways therein, said glow discharge passageways being grouped transversely to the longitudinal axes of said passageways, a reactive cathode structure spaced from said anode for particle bombardment, a vacuum envelope enclosing said anode and cathode structures, means for applying a potential difference between said anode and cathode structures of sufficient magnitude to produce simultaneous glow discharges within the plurality of glow discharge passageways and to bombard said cathode structure with positive ion particles, magnet means for producing and directing a magnetic field coaxially of and within said glow discharge passageways for enhancing the glow discharge of the apparatus, said magnet means comprising a permanent magnet and a vacuum sealed can enclosing said permanent magnet, and said magnet means positioned within said envelope.

2. A vacuum apparatus as claimed in claim 1 wherein said vacuum sealed can enclosing said permanent magnet is evacuated.

3. A vacuum apparatus as claimed in claim 1 wherein said vacuum sealed can contains a detectable gas.

4. A vacuum apparatus as claimed in claim 3 wherein said detectable gas comprises helium.

5. An electrical vacuum apparatus as claimed in claim 1 including means for flowing a coolant fluid adjacent the surface of said vacuum sealed can.

6. A vacuum apparatus as claimed in claim 5 wherein said coolant means comprises a coolant fluid conduit abutting the surface of said vacuum sealed can.

7. An electrical vacuum apparatus utilizing the principle of particle bombardment of a cathode structure including, in combination, an anode structure having a plurality of glow discharge passageways therein, said glow discharge passageways being grouped transversely to the longitudinal axis of said passageways, a vacuum envelope enclosing said anode structure, magnet means for producing and directing a magnetic field coaxially of and within said glow discharge passageways for enhancing the glow discharge of the apparatus, said magnetic field producing means comprising a permanent magnet and a vacuum sealed can enclosing said permanent magnet, said canned magnet means positioned within said vacuum envelope, the material of said vacuum sealed can being reactive and serving as a cathode structure for particle bombardment, said vacuum sealed can being spaced from and aligned with the open ends of said discharge passageways, and means for applying a potential difference between said anode and said vacuum sealed can of sufficient magnitude to produce simultaneous glow discharges within the plurality of glow discharge passageways and to bombard said vacuum sealed can with positive ion particles.

8. A vacuum apparatus as claimed in claim 7 wherein said vacuum sealed can enclosing said permanent magnet is evacuated.

9. A vacuum apparatus as claimed in claim 7 wherein said vacuum sealed can contains a detectable gas.

10. A vacuum apparatus as claimed in claim 9 wherein said detectable gas comprises helium.

11. An electrical vacuum apparatus as claimed in claim 7 including means for flowing a coolant fluid adjacent the surface of said vacuum sealed can.

12. A vacuum apparatus as claimed in claim 11 wherein said coolant means comprises a coolant fluid conduit abutting the surface of said vacuum sealed can.

13. A vacuum apparatus as claimed in claim 7 wherein said vacuum sealed can is larger than said permanent magnet in at least one direction such that a space exists within the can for flowing a cooling fluid therewithin.

14. A vacuum apparatus of the type requiring a vacuum chamber and a magnetic field therein comprising a vacuum envelope, a permanent magnet, a continuous unbroken vacuum sealed can completely enclosing said permanent magnet in a vacuum tight manner, and wherein said permanent magnet and said continuous unbroken vacuum sealed can are disposed within said vacuum envelope.

15. A magnet structure as claimed in claim 14 wherein said continuous unbroken vacuum sealed can is evacuated.

16. A magnet structure as claimed in claim 14 wherein said continuous unbroken vacuum sealed can is of a reactive material suitable for gettering gas.

17. An electrical vacuum apparatus including, in combination, an anode structure, a cathode structure spaced from said anode structure, said anode and cathode structures adapted to maintain a glow discharge upon energization thereof, a vacuum envelope enclosing said anode and cathode structures, means for applying a potential

difference between said anode and cathode structures, magnet means disposed within said vacuum envelope for producing and directing a magnetic field between said anode and cathode structures, said magnet means comprising a permanent magnet and a vacuum sealed can enclosing said permanent magnet.

18. An electrical vacuum apparatus including, in combination, an anode structure adapted to support a glow discharge upon energization thereof, a vacuum envelope enclosing said anode structure, magnet means disposed within said vacuum envelope for producing and directing a magnetic field through said anode structure, said magnet means comprising a permanent magnet and a vacuum sealed can enclosing said permanent magnet, said permanent magnet and said vacuum sealed can disposed within said vacuum envelope, said vacuum sealed can being of reactive material and spaced from said anode structure, and means for applying a potential difference between said anode structure and said vacuum sealed can to produce a glow discharge between said anode structure and said vacuum sealed can.

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