Jan. 30, 1962 R. ZAPHIROPOULOS 3,018,944

ELECTRICAL VACUUM PUMP APPARATUS

Filed June 16, 1958 2 Sheets-Sheet 1

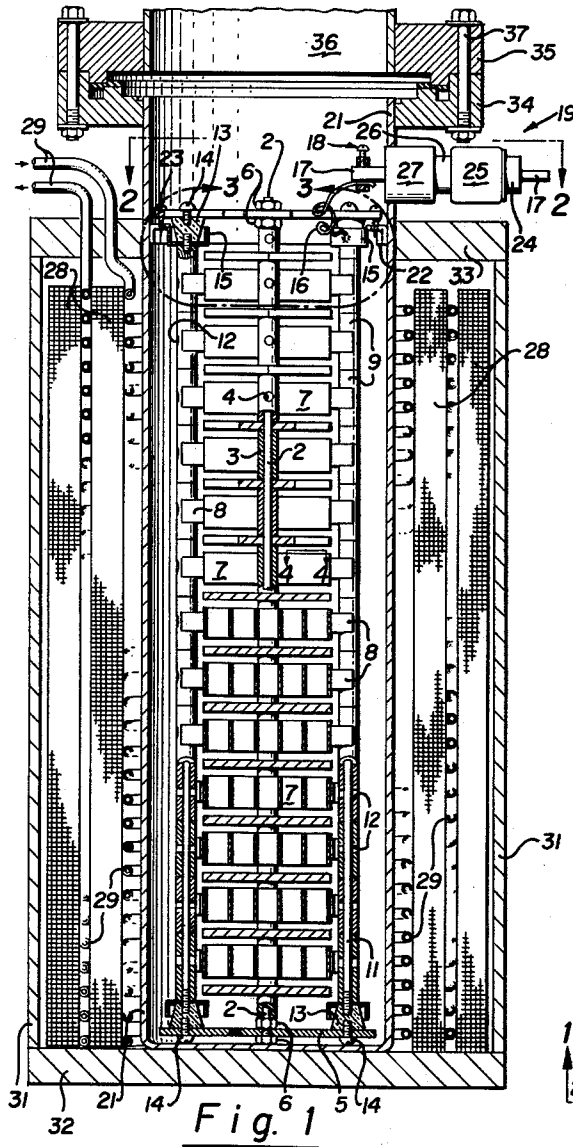


Fig. 1

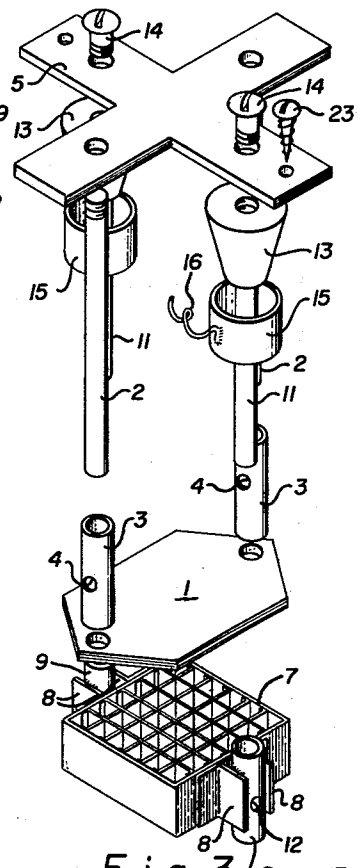


Fig. 3

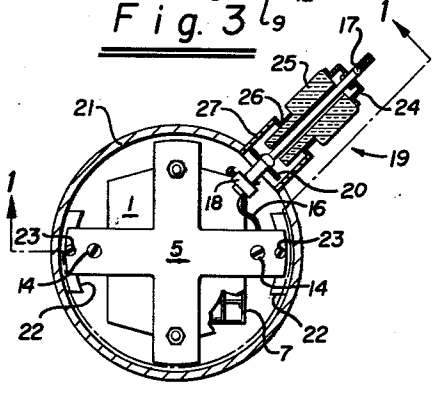


Fig. 2

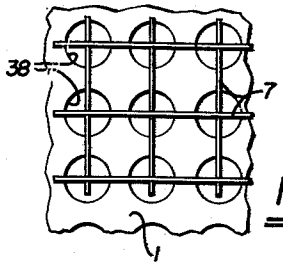


Fig. 4

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ELECTRICAL VACUUM PUMP APPARATUS

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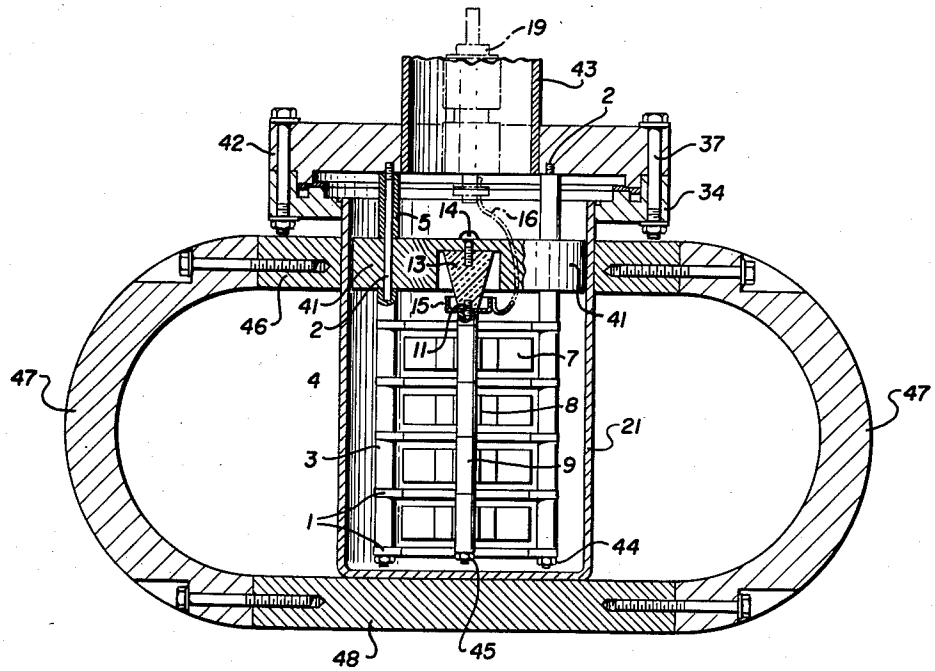


Fig. 5

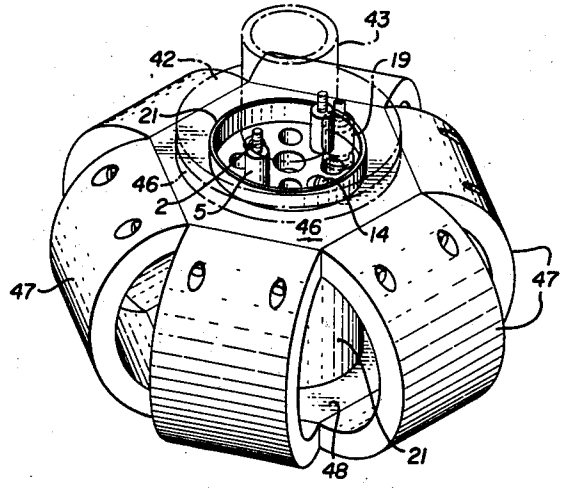


Fig. 6

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ELECTRICAL VACUUM PUMP APPARATUS

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The present invention relates in general to electrical vacuum pumps and more specifically to a novel electrical high vacuum pump of the type wherein cathode members of a reactive material are bombarded with high speed ions to disintegrate the reactive cathode material, the disintegrated cathode material condensing upon surfaces within the apparatus and there serving to getter gas molecules coming in contact therewith. Electrical vacuum pumps, using the aforementioned principle of operation, have become known in the art as getter ion vacuum pumps. Such pumps are extremely useful for providing uncontaminated high vacuums as required in many devices such as, for example, vacuum tubes, linear accelerators, electron microscopes, ammonium masers and the like.

Heretofore getter ion vacuum pumps have been constructed having a unitary cellular anode disposed between and spaced apart from two cathode plates. The unit was immersed in a strong magnetic field directed perpendicularly to the cathode plates and substantially coaxially of the cells of the anode. The anode was operated a few thousand volts more positive than the cathode plates resulting in the establishment of a glow discharged between the anode and the cathode plates whereby the cathode plates were bombarded with high speed ions thereby dislodging portions of the reactive cathode material. The disintegrated cathode material condensed upon the large area of the cellular anode to getter gas molecules within the apparatus and thereby reduce the gas pressure therewithin. While the pumping speed of such a unit was adequate for many uses there was a need for a pump having still greater pumping speed. One solution would be to scale up in size previously used pumps. The resulting scaled up pump would be awkward to use and difficult to construct due to its large diameter.

The present invention provides a novel getter ion vacuum pump wherein a plurality of anode members are interleaved with a plurality of cathode plates. The stack of interleaved members are suspended within the interior of an evacuable chamber and immersed in a strong magnetic field running substantially perpendicularly to the cathode plates. It has been found that a getter ion pump constructed in this manner has substantially enhanced pumping speed and is easy to fabricate, use and service.

The principal object of the present invention is to provide a novel getter ion vacuum pump having increased pumping speed which is relatively easy to build and service.

One feature of the present invention is the provision of a stack of interleaved anode and cathode members whereby the pumping speed of the apparatus may be greatly enhanced while permitting ease of pump assembly and replacement of used elements when required.

Another feature of the present invention is the provision of a member running longitudinally of the stack of anode and cathode members, said member serving as a mechanical support for the anode mmebers and for applying the operating potential to said anode members in use.

Another feature of the present invention is the provision of a member running longitudinally of the stack of anode and cathode members, said member serving as a mechanical support for the cathode members and for applying the operating potentials thereto in use.

Another feature of the present invention is the provision of a plurality of spacer elements slidably carried from a rod running longitudinally of a stack of interleaved cathode and anode members, said spacers disposed between successive cathode and/or anode members for allowing precise positioning of said anode or cathode members within the stack of said members as desired.

Another feature of the present invention is the provision of a tubular envelope containing therewithin and axially thereof a stack of interleaved anode and cathode members, said tubular envelope having coolant carrying tubes disposed adjacent the exterior thereof for cooling the getter ion vacuum pump, in use.

Another feature of the present invention is the provision of means for supporting the stack of interleaved anode and cathode members within the vacuum envelope from the flange utilized for joining the pump to the system it is desired to evacuate whereby construction of the apparatus is simplified and replacement of used parts facilitated.

Another feature of the present invention is the provision of a magnetic pole piece carried within the stack of interleaved anode and cathode members for enhancing the magnetic field strength and uniformity within the apparatus.

Other features and advantages of the present invention will become apparent upon a perusal of the specification taken in connection with the accompanying drawings wherein:

FIG. 1 is a longitudinal cross section view of the novel getter ion vacuum pump of the present invention,

FIG. 2 is a cross sectional view of a portion of the structure FIG. 1 taken along line 2—2 in the direction of the arrows,

FIG. 3 is an exploded perspective view of a portion of the structure FIG. 1, delineated by line 3—3,

FIG. 4 is an enlarged fragmentary view of an alternative embodiment of a portion of the structure of FIG. 1 taken along line 4—4 in the direction of the arrows,

FIG. 5 is a longitudinal cross sectional view of a novel getter ion vacuum pump of the present invention, and

FIG. 6 is a perspective view of a portion of the structure of FIG. 5.

Referring now to FIGURES 1–3 there is shown an embodiment of the present invention. More specifically, a plurality of cathode plates 1 having triangular shaped ears thereon are carried transversely of and longitudinally spaced apart along the length of two cathode support rods 2. The cathode plates 1 are made of a reactive material as of, for example, titanium or chromium. Other suitable reactive materials are molybdenum tungsten, tantalum, niobium, iron, zirconium, nickel, barium, thorium, magnesium, calcium, strontium plus other transition elements of the fourth, fifth and sixth groups of the periodic table, including the rare earths.

The cathode support rods 2 are made of a material which is structurally strong and able to withstand substantial temperatures as of, for example, stainless steel. The cathode plates 1 are slidably mounted on the two cathode support rods 2 by passing the cathode support rods 2 through two apertures in the ear portions of the cathode plates 1. The cathode plates 1 are spaced apart longitudinally of the cathode support rods 2 via a plurality of hollow cylindrical cathode spacers 3, as of, for example, stainless steel.

The cathode spacers 3 are apertured at 4 to allow gases trapped within the spaces between the spacer and the cathode support rods 2 to easily escape during operation of the pump. The cathode support rods 2 are anchored at their end portions to upper and lower cross arm 5 via lock nuts 6. The cross arms 5 are made of a material

which is structurally strong and able to withstand substantial temperatures as of, for example, stainless steel.

A plurality of cellular anodes 7 which may be fabricated, for example, from titanium sheet metal approximately 0.015 inch thick spot-welded together are carried via four brackets 8 disposed on opposite sides thereof. The brackets 8 may be of, for example, titanium sheet metal spot-welded to the cellular anode 7 and the brackets 8 in turn are spot-welded to tubular anode spacers 9 as of, for example, stainless steel.

Two anode support rods 11 as of, for example, stainless steel are slidably inserted within the hollow anode spacers 9. The two anode support rods 11 are quadraturally placed with respect to the cathode support rods 2 and extend longitudinally of the stacked cellular anodes 7 and cathode plates 1. The anode spacers 9 are suitably apertured at 12 to allow gases within the space between the anode support rods 11 and the anode spacers 9 to be easily pumped during operation of the pump.

The ends of the anode support rods 11 are threaded to mate with the internal threads of frustro conically shaped anode high voltage insulators 13 which in turn are carried from the upper and lower cross arms 5 via suitable screws 14. Hollow cylindrical anode insulator shields 15 are captured between the insulators 13 and anode spacers 9 at the ends of the anode support rods 11. The insulator shields 15 extend coaxially of and slightly spaced apart from the anode high voltage insulators 13 to prevent the condensation of disintegrated cathode material upon the anode high voltage insulators 13 and thus produce inadvertent shorting thereof.

A high voltage lead 16 is fixedly secured to the anode insulator shield 15 as by, for example, soldering and is clamped via clamp 18 at its other end to the center conductor 17 of a high voltage lead-in insulator assembly 19.

The stack of interleaved anodes 7 and cathode plates 1 is carried between the upper and lower cross arms 5 and is suspended within a hollow tubular envelope 21 as of, for example, stainless steel. The stacked assembly is carried from the tubular envelope 21 via two brackets 22 spot-welded to the inside surface of the envelope 21 substantially at the open end thereof. The upper cross arm 5 is fixedly secured to the two brackets 22 via two sheet metal screws 23.

The high voltage lead-in insulator assembly 19 includes the center conductor 17 as of, for example, stainless steel extending radially outward of the tubular envelope 21 through an aperture therein. A centrally apertured cup member 24 as of, for example, Kovar is fixedly secured substantially at the outer mostly extremity of the center conductor 17 as by, for example, brazing. A hollow cylindrical insulator 25 as of, for example, ceramic is disposed coaxially of the center conductor 17 and is fixedly secured at one end to the cup shaped frame member 24 as by, for example, a metal to ceramic seal. The ceramic insulator 25 is externally recessed at its other end and has affixed thereto and coaxially thereof an annular metallic frame member 26 as of, Kovar. An annular insulator shield 20 is carried transversely of the center conductor 17 for preventing disintegrated cathode material from condensing on the insulator 25. Frame member 26 is sealed to and closes off the open end of a hollow cylindrical adapter 27 as of, for example, stainless steel. The hollow cylindrical adaptor 27 is carried from the inside periphery of the aperture in the side wall of the tubular envelope 21 as by, for example, a heliarc weld.

An electrical solenoid 28 is disposed concentrically of the tubular envelope 21 for producing a magnetic field directed axially of the interleaved stack of cellular anodes 7 and cathode plates 1. A hollow coolant tube 29 is wound in a helical fashion and affixed to the inside peripheral surface of the solenoid 28 extending substantially the entire length thereof. The hollow coolant tube 29 extends radially from the inner helix therein to a position of larger diameter and is wound into another helix and sandwiched between two coaxial halfs of the solenoid 28. The hollow coolant tube 29 is supplied with fluid coolant from a source, not shown.

A hollow cylindrical magnet yoke 31 as of, for example, iron circumscribes the solenoid 28 and is closed off at one end via a circular pole piece 32 as of, iron. The other end of the magnet yoke 31 is closed off via an annular pole piece 33 centrally apertured to receive the tubular envelope 21 slidably therethrough.

An annular flange 34 as of, for example, stainless steel is fixedly secured to the open end of the tubular envelope 21 as by, for example, a heliarc weld. The flange 34 mates with a similar flange member 35 carried upon the extremity of a hollow exhaust tubulation 36 communicating with the apparatus it is desired to evacuate. The flanges 34 and 35 are provided with suitable mating ridges thereon for compressing therebetween a soft metal gasket as of, for example, copper to assure a vacuum tight connection. The flanges 34 and 35 are pulled together via a plurality of bolts 37 spaced about the periphery of the flanges 34 and 35.

In operation the tubular envelope 21 is preferably exhausted to a pressure of at least 10^{-4} millimeters of mercury by, for example, a mechanical vacuum pump, not shown. A positive potential with respect to the potential of the cathode plates 1 as of, for example, 3 kv. is applied to the anode members 7 via center conductor 17 of the high voltage insulator assembly 19 and lead 16. The cathode plates 1 are electrically connected to the tubular envelope 21 which is preferably operated at ground potential. The solenoid 28 is energized with electrical current producing a magnetic field of approximately 1,000 gauss directed longitudinally of the interleaved stack of cellular anodes 7 and cathode plates 1.

When the operating potentials are applied a glow discharge is initiated between the interleaved anode and cathode members. The total glow discharge is subdivided by the anode cells or openings into a plurality of separated glow discharge columns, the discharge columns extending through the anode cells or glow discharge passageways which extend in the direction of the magnetic field. Positive ions created by the glow discharge are accelerated under the applied electric field between anodes 7 and cathode plates 1 and are caused to bombard the cathode plates 1 thereby disintegrating portions of the reactive cathode plates 1. The disintegrated portions of the cathode plates 1 diffuse within the interior of the tubular envelope 21 and condense upon the surfaces of the cellular anodes 7. Gas molecules coming in contact with the disintegrated cathode material are entrapped thereon and effectively removed from the gaseous state thereby reducing the pressure within the tubular envelope 21 and other structures communicating therewith.

After the pump has been in operation for a considerable period of time a substantial accumulation of atomized cathode material will have coated the cellular anodes 7 and a substantial proportion of the cathode plates 1 will have been eroded away due to the ion bombardment. The wornout cathode plates 1 may be easily replaced due to the unique construction of the present vacuum pump by removing the stack of interleaved cathodes 1 and anodes 7 and replacing the cathode plates 1 with new plates 1. At the same time the cellular anodes 7 may be replaced if required or merely sandblasted or chemically treated to remove the accumulation of cathode material. The elements are then reassembled and inserted within the tubular envelope 21.

It has been found that the pumping speed of a pump constructed in the above-described manner is substantially enhanced over the pumping speed obtainable with a single cellular anode 7 disposed between adjacent cathode plates 1. It has been found that the pumping speed of a getter

ion pump is approximately proportional to the total cross sectional area of the cellular anodes 7.

The stack of alternately spaced anodes 7 and cathode plates 1 is spaced a substantial distance from the side walls of the tubular envelope 21 to facilitate the passage of gases therearound and into the spaces between the anodes 7 and cathode plates 1 to enhance the pumping speed.

The pumping speed of the apparatus (see FIG. 4) may be further increased by providing a plurality of apertures 38 in the cathode plates 1, said apertures 38 having their centers registering with the innersection of the vanes forming the cellular anodes 7. The use of apertured cathode plates for enhancing gas access is claimed in and forms the subject matter of applicant's co-pending divisional application, U.S. Serial No. 151,339, filed November 9, 1961. When the cathode plates 1 are apertured in this manner the transparency of the cathodes 1 to gases diffusing into the stack of interleaved anodes 7 and cathode plates 1 is substantially increased thereby enhancing the pumping speed of the apparatus. The amount of cathode material that is sputtered from the apertured cathode plates 1 is substantially the same as the amount of cathode material sputtered from the nonapertured cathode plates 1 because the cellular anode 7 has an ion focusing effect causing substantially all of the ion bombardment of the cathode plates 1 to take place in alignment with the central portion of the individual cells making up the cellular anode 7.

Referring now to FIGURES 5 and 6 there is shown another embodiment of the present invention. More specifically, this embodiment is similar to the structure shown in FIGURES 1–4 with the exception that the stack of alternately spaced anodes 7 and cathode plates 1 is carried from a flange assembly rather than from the inside of the tubular envelope 21. In addition, permanent magnets employing a pole piece inside of the tubular envelope 21 have been utilized for supplying the magnetic field axially of the stack of anodes 7 and cathode plates 1.

The cathode support rods 2 carry the cathode plates 1 transversely thereof and longitudinally spaced apart via cathode spacers 3. Also carried transversely of the cathode support rods 2 is an apertured circular pole piece 41 as of, for example, iron. The ends of the cathode support rods 2 are threaded for mating with the internal threads of suitably placed bores in an annular flange 42 as of, for example, stainless steel which in turn is carried at the end of an exhaust tubulation 43. The cathode plates 1 are held on the cathode support rods 2 via nuts 44 threaded over the free end portions thereof.

The anode support rods 11 are quadraturally spaced to the cathode support rods 2 and carry therefrom and transversely thereof the cellular anode members 7 via brackets 8 and anode spacers 9. The anode support rods 11 are anchored in anode high voltage insulators 13 which are carried within recesses provided in the pole piece 41 via screws 14. The cellular anodes 7 are captured on the anode support rods 11 via nuts 45 threaded over the free end portion of the anode support rods 11.

The positive operating voltage is applied to the cellular anode members 7 via the high voltage lead-in insulator assembly 19 and lead 16. The lead-in insulator assembly 19 is carried from the annular flange 42 and extends through a suitable aperture therein.

The pole piece 41 is provided with a plurality of apertures therethrough to facilitate the flow of gas into the stacked pumping structure. The apertured magnetic pole piece, for enhancing gas access, is claimed in and forms the subject matter of applicant's co-pending divisional application, U.S. Serial No. 151,339, filed November 9, 1961. The pole piece 41 is closely spaced to the side walls of the tubular envelope 21. A centrally apertured hexagonal plate 46 as of, for example, iron is carried from the tubular envelope 21 adjacent the pole piece 41 and forms a continuation of the pole piece 41. The flat sides of the hexagonal plate 46 carry a plurality of C shaped permanent magnets 47 as of, for example, alnico V. The C shaped permanent magnets 47 are secured at their ends via bolts to the flat sides of hexagonal plates 46 and 48 forming the pole pieces of the permanent magnets. Plate 48 is made of a magnetic permeable material as of, for example, iron.

Flange 34 which is fixedly secured to the tubular envelope 21 substantially at the open end thereof mates with flange 42 for compressing therebetween a soft metal gasket as of, for example, copper to assure a vacuum tight seal at the joint. The flanges 42 and 34 are held together via a plurality of bolts 37 spaced about the perimeter of the flanges.

The pump embodiment shown in FIGURES 5 and 6 has substantially the same mode of operation as the pump previously described with regard to FIGURES 1–4. However, the pump is simplified to the extent that the stack of alternately spaced anodes 7 and cathode plates 1 is supported directly from the flange 42. Moreover, the use of a current source and coolant tubes for the solenoid 28 is dispensed with. The magnetic field is provided by a plurality of permanent magnets 47. The provision of the pole piece 41 internally of the tubular envelope 21 allows a more uniform magnetic field within the tubular envelope 21.

Additional anodes 7 and cathode plates 1 may be added to the pump described in FIGURES 5 and 6 by extending the envelope 21 to accommodate the added members and by providing additional C shaped magnets positioned longitudinally of the envelope 21 and preferably provided with additional internal and external pole pieces 41 and 46 respectively as required.

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. In an electrical vacuum pump apparatus including, means forming an anode, means forming a cathode, said anode means having a plurality of members, said cathode having a plurality of members made of a reactive material, said anode members being interleaved with said cathode members to form a stack of alternately spaced apart anode and cathode members, means for providing a magnetic field directed longitudinally of the stack of said anode and cathode members, means for applying a positive potential to said anode means with respect to said cathode means for initiating a glow discharge therebetween, means extending longitudinally of the stack of said anode and cathode means for mounting said anode means slidably therefrom, means for preventing inadvertent slippage of said anode means with respect to said mounting means and being removable as desired whereby said anode means may be readily removed from said anode mounting means for replacement and cleaning as desired.

2. In an electrical vacuum pump apparatus including, means forming an anode, means forming a cathode, said anode means having a plurality of members, said cathode means having a plurality of members made of a reactive material, said anode members being interleaved with said cathode members to form a stack of alternately spaced apart anode and cathode members, means for providing a magnetic field directed longitudinally of the stack of said anode and cathode members, means for applying a positive potential to said anode means with respect to said cathode means for initiating a glow discharge therebetween, means disposed longitudinally of the stack of said anode and said cathode members for slidably supporting therefrom said cathode members whereby said cath-

ode members may be readily removed from said support means for replacement as desired.

3. The apparatus according to claim 2 wherein said cathode support means includes a rod extending longitudinally of the stack of anode and cathode means, said cathode members being carried transversely of said rod, means for spacing apart successive cathode members, and said spacer means being supported from and slidable with respect to said support rod as desired.

4. In an electrical vacuum pump apparatus, including, means forming an anode, means forming a cathode, said anode means having a plurality of members, said cathode means having a plurality of members made of a reactive material, said anode members being interleaved with said cathode members to form a stack of alternately spaced apart anode and cathode members, means for providing a magnetic field directed longitudinally of the stack of said anode and cathode members, means for applying a positive potential to said anode means with respect to said cathode means for initiating a glow discharge therebetween, a tubular envelope for containing therewithin the stack of alternately spaced apart anode and cathode members, and means for conveying coolant therethrough disposed adjacent said tubular envelope for carrying away excess heat energy conducted to said tubular envelope, in use.

5. In an electrical vacuum pump apparatus including, means forming an anode, means forming a cathode, said anode means having a plurality of members, said cathode means having a plurality of members made of a reactive material, said anode members being interleaved with said cathode members to form a stack of alternately spaced apart anode and cathode members, means for providing a magnetic field directed longitudinally of the stack of said anode and cathode members, means for applying a positive potential to said anode means with respect to said cathode means for initiating a glow discharge therebetween, means extending longitudinally of the stack of said anode and cathode means for mounting said anode means therefrom, a hollow tubular envelope closed at one end for containing therewithin the stack of alternately spaced apart anode and cathode members, means disposed substantially at the open end of said tubular envelope for carrying therefrom said anode mounting means whereby the stack of alternately spaced anode and cathode members may be readily removed from said tubular envelope as desired.

6. In an apparatus as claimed in claim 5 wherein said means for carrying said mounting means includes a cross arm carried from the inside surface of said tubular envelope.

7. In an apparatus as claimed in claim 5 wherein said means for carrying said mounting means includes a flange member sealed to said tubular envelope via the intermediary of a take-apart vacuum seal, whereby the stack of alternately spaced anode and cathode members may be easily removed from said tubular envelope as desired.

8. The apparatus according to claim 5 including means forming a magnetic pole piece carried transversely of and within the stack of alternately spaced apart anode and cathode members and cooperating with said magnetic field producing means to enhance the magnetic field uniformity throughout the stack of said anode and cathode members.

9. The apparatus according to claim 5 wherein said magnetic field providing means includes a permanent C-shaped magnet.

References Cited in the file of this patent

UNITED STATES PATENTS

2,636,664	Hertzler	Apr. 28, 1953
2,850,225	Hub	Sept. 2, 1958