Feb. 27, 1962 R. E. ELLIS 3,022,933

MULTIPLE ELECTRON BEAM ION PUMP AND SOURCE

Filed June 1, 1959 2 Sheets-Sheet 1

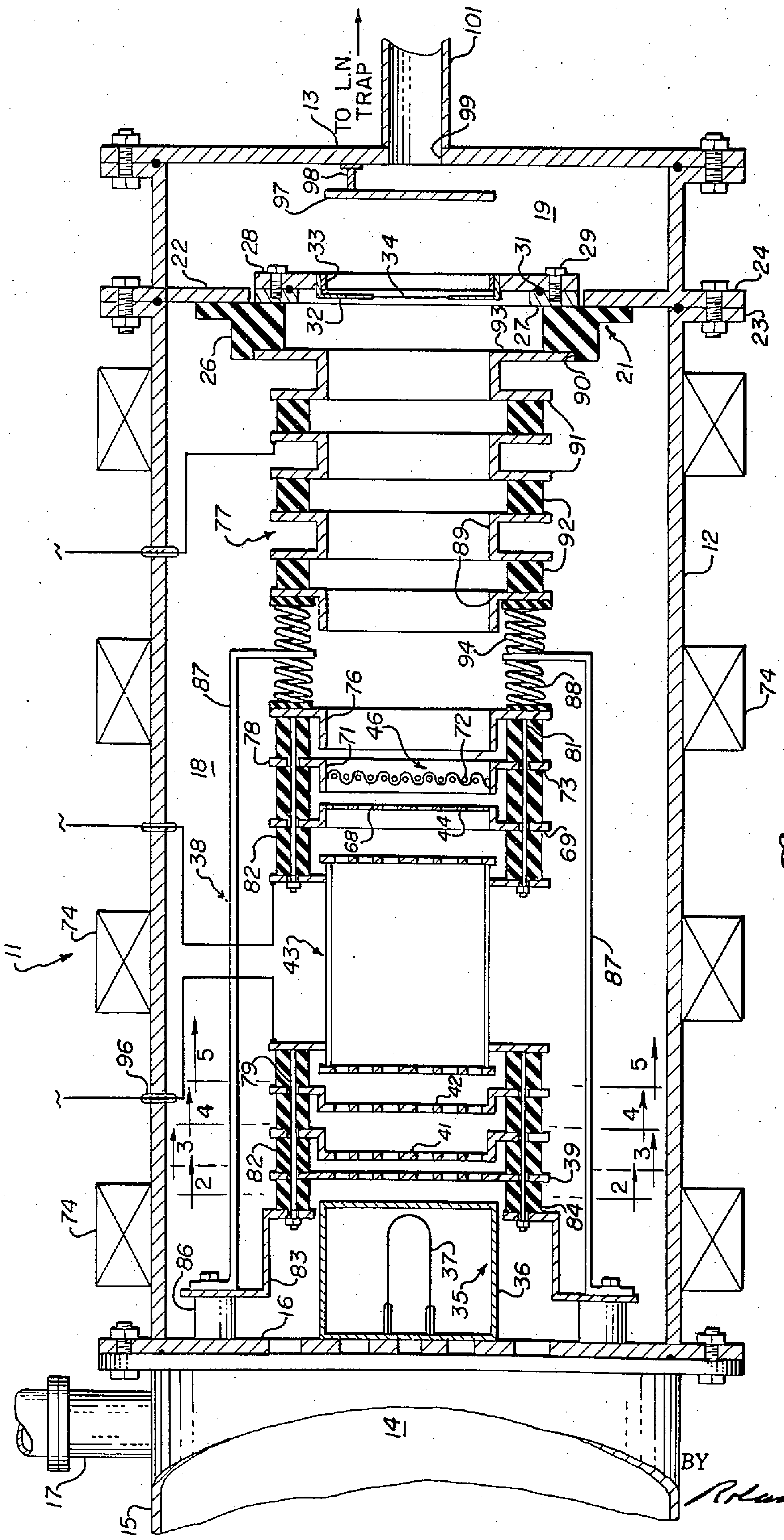


Fig. 1.

INVENTOR.
ROBERT E. ELLIS
BY
Roland A. Anderson
ATTORNEY.

Feb. 27, 1962 R. E. ELLIS **3,022,933**

MULTIPLE ELECTRON BEAM ION PUMP AND SOURCE

Filed June 1, 1959 2 Sheets-Sheet 2

Fig. 2.

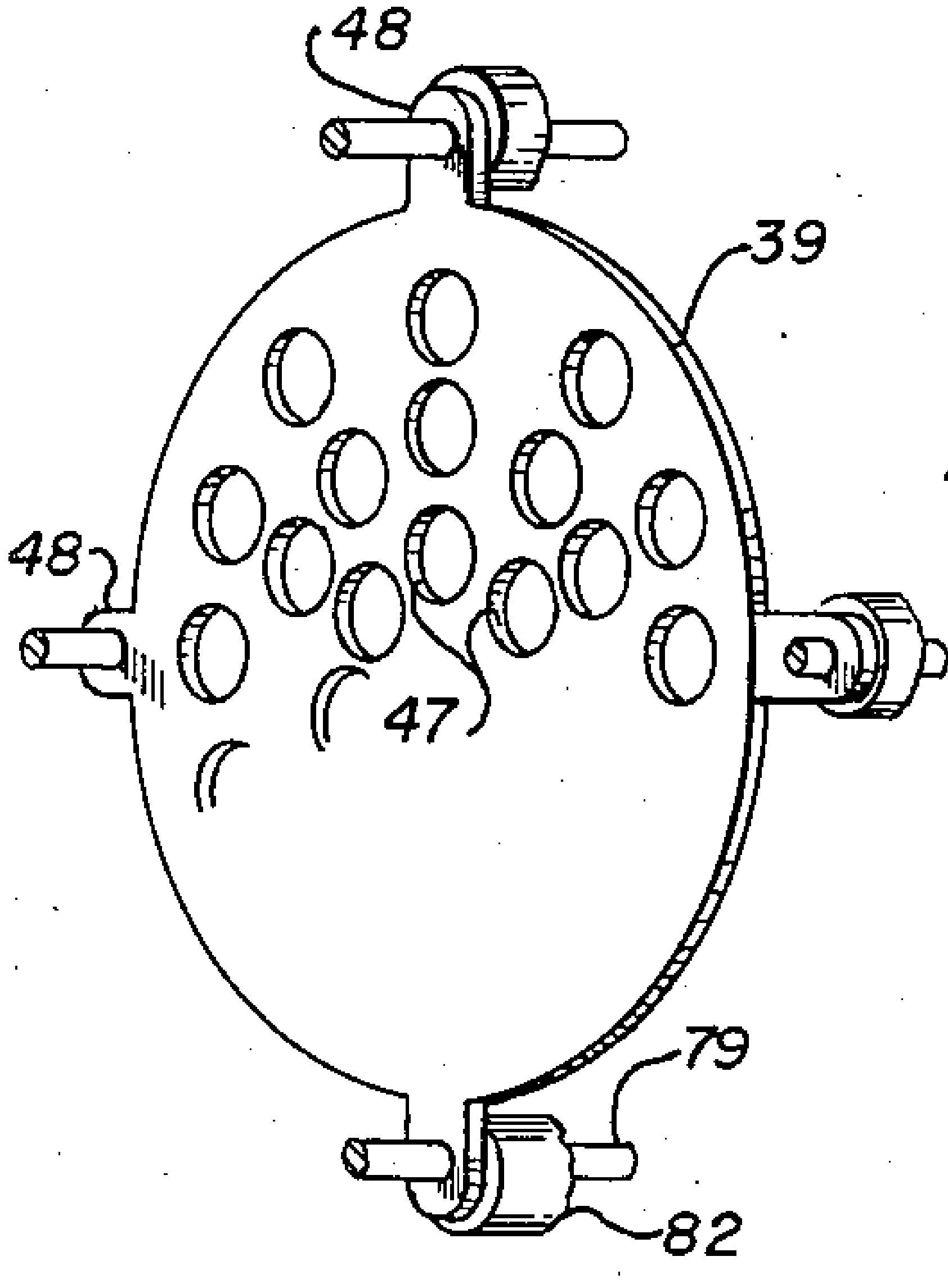


Fig. 3.

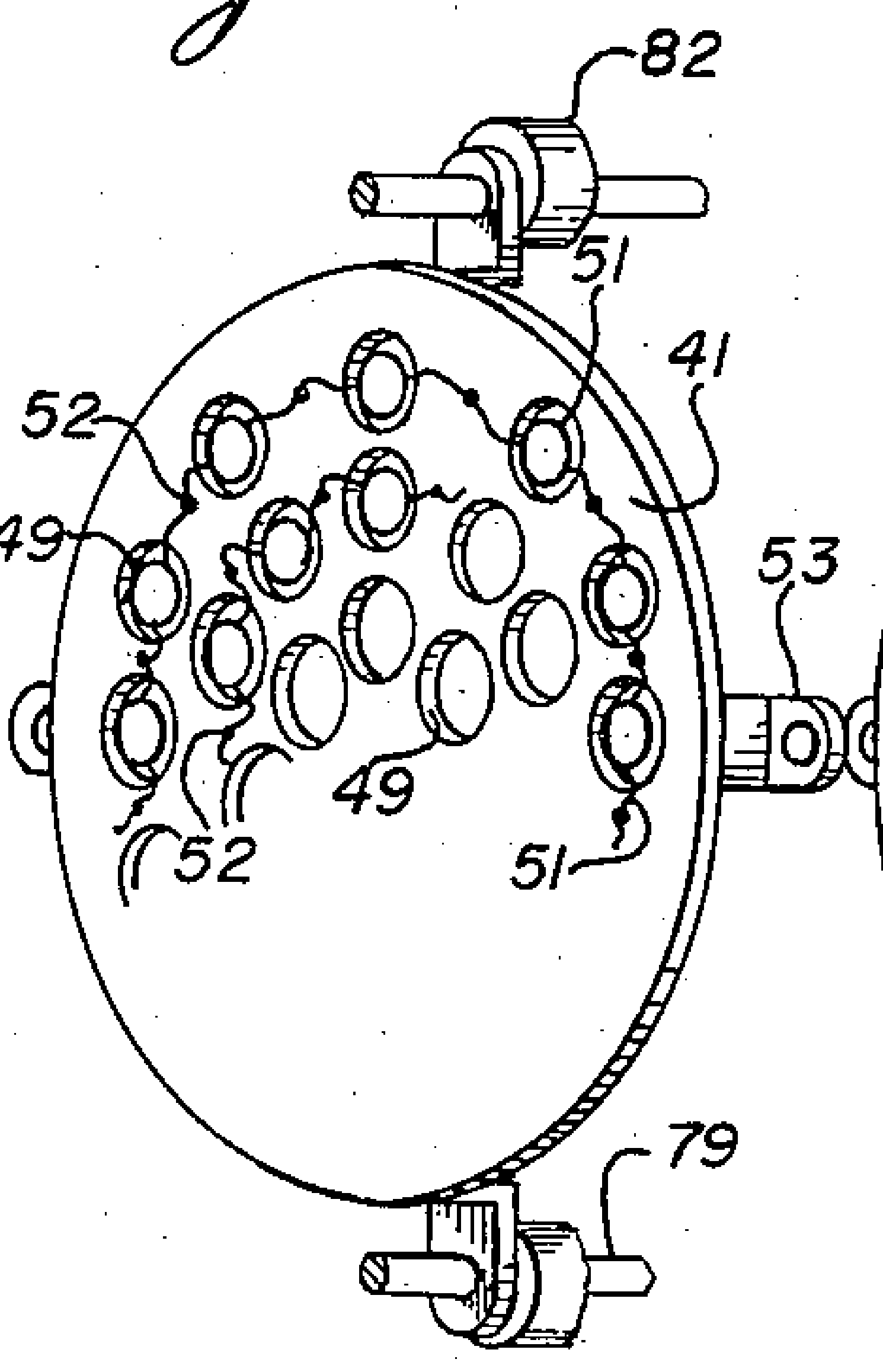


Fig. 4.

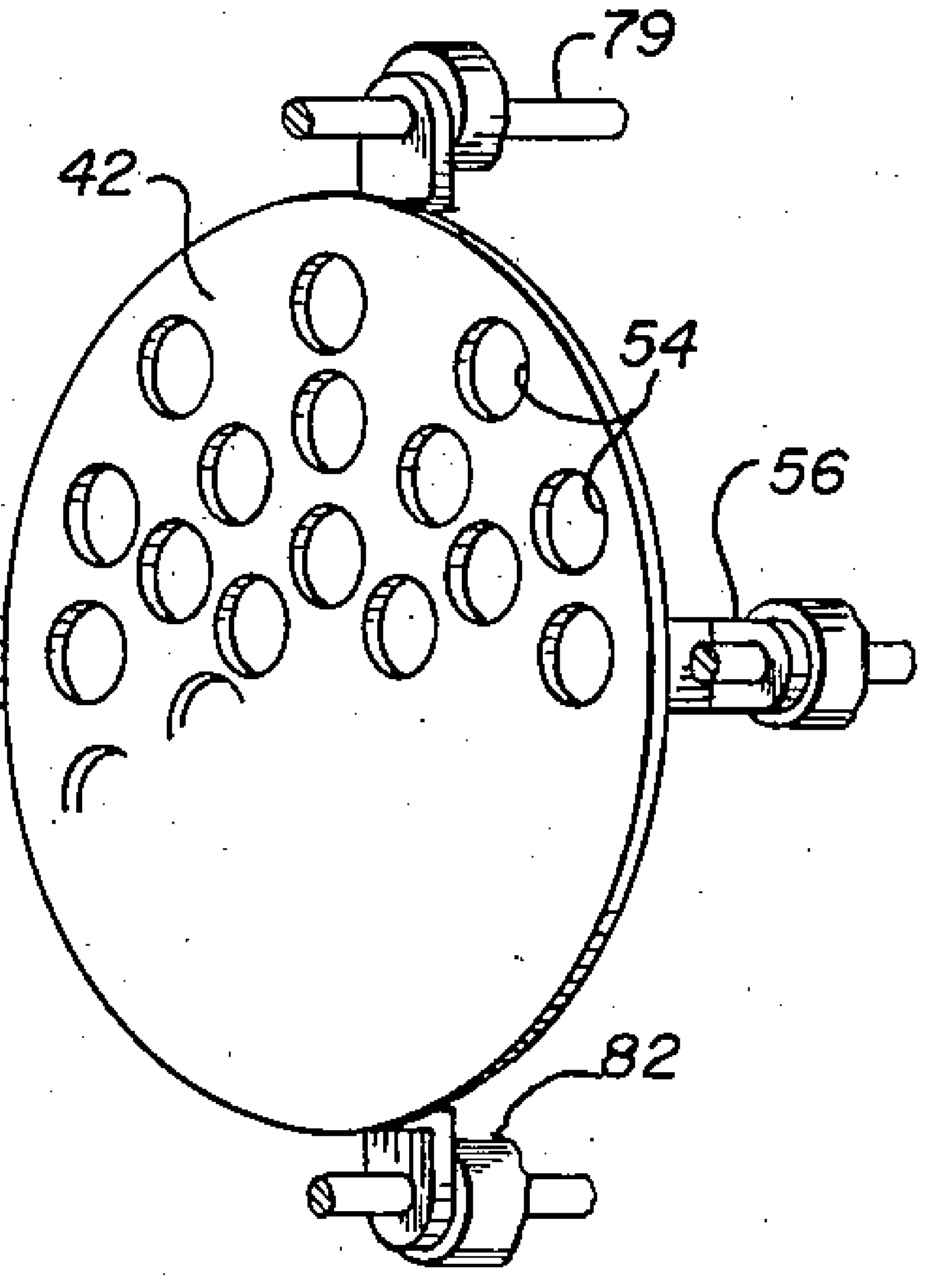
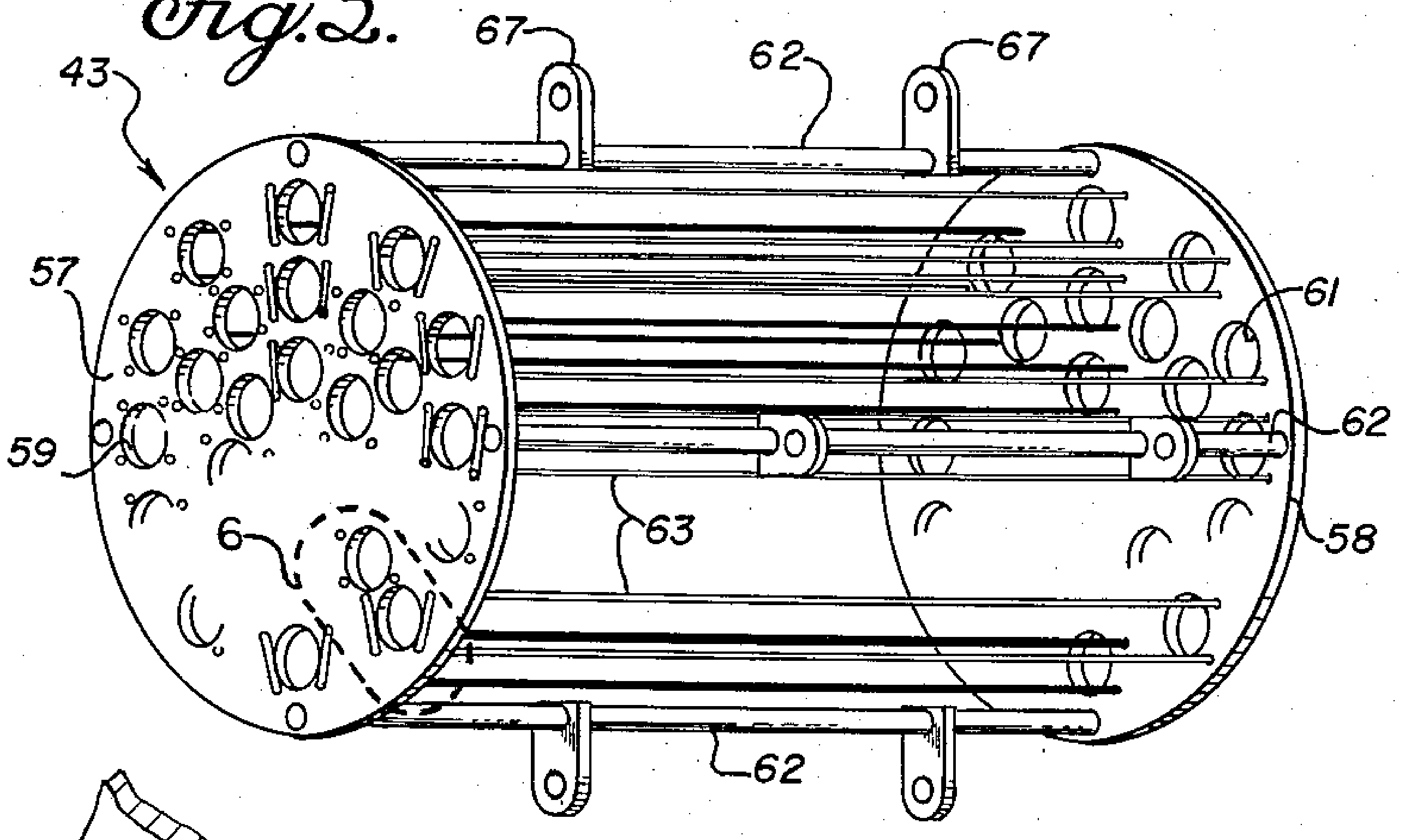


Fig. 5.



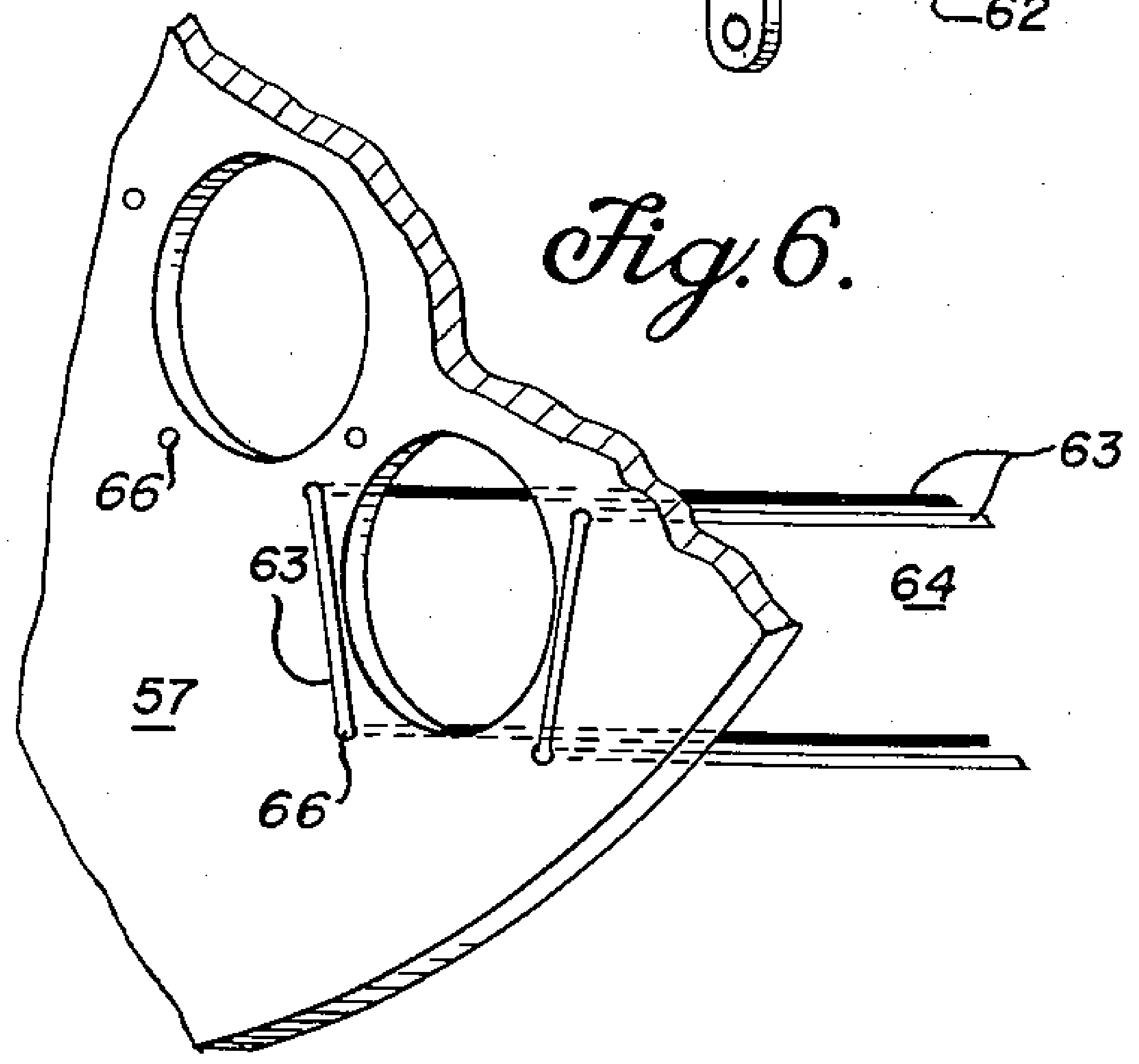


Fig. 6.

INVENTOR.
ROBERT E. ELLIS

BY

Roland A. Anderson

ATTORNEY

United States Patent Office

3,022,933
Patented Feb. 27, 1962

3,022,933

MULTIPLE ELECTRON BEAM ION PUMP AND SOURCE

Robert E. Ellis, Danville, Calif., assignor to the United States of America as represented by the United States Atomic Energy Commission

Filed June 1, 1959, Ser. No. 817,426
11 Claims. (Cl. 230—69)

The present invention relates generally to certain types of ion pumps useful also as ion sources, and more particularly to such a device which employs a multiple electron beam of high electron density for more efficient ion production.

Certain classes of gaseous discharge devices, e.g., high intensity PIG discharge devices, are generally useful as both ion pumps and ion sources. Such devices have been well known for several years past in the field of nuclear physics and have found considerable usage in connection with various particle accelerators and the like. In general these discharge devices consist of a cylindrically shaped evacuated chamber provided with electrodes at either end of the axis of the cylinder, one of which electrodes provides a source of electrons. A magnetic field parallel to the axis of the cylinder causes emitted electrons to move in helical paths centered around a group of magnetic lines of force. The electrons are reflected as they approach an electrode and travel back and forth many times along their helical paths as a refluxing electron beam before they finally strike one of the surfaces and are absorbed. These numerous reflections of the electrons and their helical paths increase the probabilities of collisions between the electrons and residual gas molecules within the evacuated chamber, many fold over a single straight passage of each electron from one electrode to the other. The aforesaid collisions effect ionization of the gas molecules by knocking electrons therefrom with an attendant production of ions and additional electrons. The ions thus formed may be removed from the device for reconversion to neutral gas and subsequent removal of the neutrals as by means of a forepump to produce an ionic pumping action. Alternatively, the ions may be directly injected into ion utilization apparatus such as a particle accelerator.

Presently available gaseous discharge devices of the foregoing type, useful both as ion pumps and sources, have not heretofore been satisfactory from the standpoint of reducing vacuums to sufficiently low levels or in providing the required ion densities for use in certain ion utilizing machines. The concentration of moving electrons in the electron beam of these gaseous discharge devices produce ions in definite quantities related directly to the pressure of the residual gas in the evacuated envelope. Thus as the residual gas pressure is reduced there are fewer gas molecules available for bombardment to form ions. A point is eventually reached where gas leakage into the evacuated envelope equals the gas removed. Hence, the ion production rate is limited by such condition and a fixed minimum pressure is established.

The present invention, by the provision of a plurality of electron beams in the space previously occupied by one, greatly increases the probability of collisions occurring between electrons and residual gas molecules and materially increases the ion production rate. As a result, the minimum pressure attained is relatively lower than that produced by a conventional single beam device, and the density of ions available for extraction is greatly improved. The invention further provides a diaphragm through which the ions are impelled, and which serves as a definite barrier between the evacuated low pressure volume and a higher pressure exhaust region of forevac dimensions. The definite removal of gas molecules from the space where a high degree of evacuation is required is thus greatly improved.

Therefore, it is an object of the present invention to provide an improved gaseous discharge device useful both as an ion pump and ion source.

Another object of the present invention is to provide a gaseous discharge device having a greater average density of electrons in the ionizing beam.

Still another object of the present invention is to produce increased numbers of ions in a residual gas at a given pressure, compared to the number of ions produced at such pressure by conventional ion pumps and ion sources.

A further object of the present invention is to provide improved means for the removal of ions from a gaseous discharged device following their formation.

An important object of the invention is the provision of a multiple electron beam for the ionization of gas and production of ions at increased production rates.

Other objects and advantages of the present invention will be made obvious to those skilled in the art by the following description when considered in relation to the accompanying drawing, of which:

FIGURE 1 is a longitudinal sectional view of the present invention embodied as an ion pump and taken on a plane through the axis;

FIGURE 2 is a perspective view of the cathode shield structure of the ion pump as viewed from plane 2—2 of FIGURE 2;

FIGURE 3 is a perspective view of the filament mesh electrode of the present pump as viewed from plane 3—3 of FIGURE 1;

FIGURE 4 is a perspective view of the ion trapping grid of the ion pump as viewed from plane 4—4 of FIGURE 1;

FIGURE 5 is a perspective view depicting the novel multiple beam forming anode of the ion pump as viewed from plane 5—5 of FIGURE 1; and

FIGURE 6 is a perspective view of a broken-out portion of the beam forming anode of FIGURE 5.

Considering now the preferred structure embodying the present invention as illustrated in the drawing, and referring particularly to FIGURE 1, item **11** denotes an ion pump in accordance with the present invention including a vacuum tank **12** preferably of cylindrical form and constructed of magnetically pervious material also suitable for high vacuum service, such as non-magnetic stainless steel. One end of tank **12** is closed by transverse plate **13** hermetically sealed thereto. Closure plate **13** may be fabricated from similar material as the tank **12**, stainless steel for instance.

The other end of vacuum tank **12** is adapted for vacuum sealed communicable connection to a space **14** enclosed by vessel **15** which is to be evacuated to a desired extremely low pressure. Vessel **15**, for example, may constitute various charged particle acceleration or other apparatus. To accomplish such connection, the end of tank **12** is preferably provided with a vacuum flange for connection to a conformed flange of the vessel **15**. A perforated support member **16** is rigidly secured transversely within the end of the tank for interiorly mounting various elements of the pump as subsequently described. The low pressure atmosphere produced within the space **14** as by means of a conventional pump coupled to a pumping port **17** of vessel **15** hence freely communicates with the interior of tank **12** through the perforations of support member **16**. Ionic pumping action in accordance with the present invention as occurs in tank **12** as subsequently described, hence operates to reduce further the pressure of the space **14** to extremely high vacuum dimensions, for example, of the order of 10^{-10} mm. of mercury, which ultra low pressures cannot be attained by means of the unbaffled conventional pump coupled to port **17** alone.

The interior volume within tank **12** is effectively partitioned into a pumping region **18** in communication with vessel **15** and an exhaust region **19** by means of a transverse accelerated ion pervious division member **21** coaxially secured within the tank relatively near to end plate **13**. More particularly, division member **21** preferably comprises a metallic ring **22** transversely secured within tank **12** as by pressure sealed attachment between a pair of external flanges **23, 24** provided at the tank for this purpose. Within metallic ring **22** there is secured an annular insulating member **26**, having an internal annular metallic flange **27** secured to the face of the insulating member adjacent exhaust region **19**. The connections between the insulating member and ring **22** and flange **27** are accomplished by any one of various conventional metal to insulator sealing methods. A metallic mounting ring **28** is secured in pressure sealed relation to the face of flange **27** as by means of flange bolts **29** and an annular sealing element **31** interposed therebetween. A cup-shaped diaphragm **32** is in turn retained in closing relation within the center opening of mounting ring **28** preferably by means of a retaining ring **33**, the rim portion of the diaphragm being firmly held between the retaining ring and mounting ring. Diaphragm **32** is pervious to accelerated ions while being impervious to gas molecules. To facilitate the foregoing, diaphragm **32** is preferably fabricated from $\frac{1}{10}$ mil aluminum foil and has a prepared central region **34** of a thin film of aluminum oxide (Al_2O_3) of no more than three thousand angstrom units thickness. The thin film of aluminum oxide is penetrable by ions accelerated by from 25,000 to 50,000 volts potential.

Within the pumping region **18** of vacuum tank **12**, there is provided an electron emissive cathode **35** which is preferably provided as a hollow cylinder **36** having a heater filament **37** mounted therein proximate the end face thereof. Cathode **35** is coaxially secured to perforated support member **16** and lead-in conductors (not shown) may be connected to filament **37** to facilitate the supply of electrical current therethrough in the conventional manner. Upon energization of the filament heating of cathode cylinder **36** takes place by electron bombardment, the filament being about 1000 volts lower in potential. Electrons are thermionically emitted from cylinder **36** in copious quantities from the end face thereof into region **18**.

Also mounted within pumping region **18** of the tank **12** in spaced coaxial relationship to the cathode **35** is a multiple electron beam forming assembly **38** in accordance with the salient aspects of the invention for forming the electrons emitted from the cathode into a plurality of longitudinally extending beams. Such multiple beams provide a means for ionizing gas within the pumping region **18** at ionization rates heretofore unrealizable.

The multiple electron beam forming assembly **38** preferably comprises a cathode shield electrode **39** (see FIGURE 2), a filament mesh electrode **41** (see FIGURE 3), an ion trapping anode electrode **42** (see FIGURE 4), multiple beam anode structure **43** (see FIGURE 5), a second ion trapping anode **44** substantially identical to anode **42**, and an electron reflector grid **46**, all arranged in consecutive coaxially spaced series.

The cathode shield **39** as shown in FIGURE 2 is best provided as a metallic circular disc with a plurality of uniformly distributed holes **47** drilled therethrough. Shield **39** is additionally provided with radially projecting mounting tabs **48** to facilitate mounting of the shield coaxially proximate the face of cathode cylinder **36** in a manner which is subsequently described. Holes **47** are drilled in a pattern uniformly covering the entire disc although only a portion are shown in the figure. Electrons emitted from the cathode **35** when filament **37** is heated in passing through the holes **47** of the cathode shield **39** emerge therefrom as a plurality of uniformly distributed separate electron streams. Electrons which do not pass through the holes **47** are generally reflected to the emitter surface of the cathode but those not reflected are absorbed.

The filament mesh **41** which is the next axially spaced element following the cathode shield **39** is best provided as shown in FIGURE 3 as a metallic cup with holes **49** drilled through its transverse face in registry with the holes **47** of cathode shield **39**. Wire mesh **51** is secured to the surface of filament mesh electrode **41** as at points **52** by welding or other suitable means. In addition, mounting tabs **53** extend radially outward from the rim of electrode **41** at the end opening thereof. The cup configuration of the filament mesh electrode **41** facilitates proper spacing of same from the cathode shield **39**. When mounted as subsequently described, the holes **49** are drilled the same size and in the same pattern as holes **47** and registry is obtained therebetween when mounting tabs **53** are aligned with tabs **48** of cathode shield **39**. The wire mesh **51** is provided for the purpose of producing electrons when heated and therefore one or more loops of the filament may be located over each of the holes **49** and may be constituted of a material such as thoriated tungsten for instance. Since the holes **49** and the loops of filament **51** over them line up axially with the holes **47** of the cathode shield **39**, the electrons emerging from holes **47** tend to pass through holes **49** and will impinge on the loops of filament mesh **51** causing these loops to heat and become separate emitters to establish a multiplied quantity of electrons in the streams thereof emerging from the holes **49**.

The ion trapping anode **42** as shown in FIGURE 4 is preferably formed as a cup having a substantially identical configuration as filament mesh electrode **41**. The transverse face of ion trapping anode **42** is drilled with holes **54**, of the same size and pattern as the aligned holes of cathode shield **39** and filament mesh electrode **41**. The holes **54**, moreover, have the proper orientation with respect to mounting lugs **56** projecting radially from the rim of anode **42** that when these lugs are axially aligned with the tabs **53** of filament mesh electrode **41**, the holes **54** are in registry with holes **49**. The purpose of this anode is to introduce an electrical field at such a point in the pumping region **18** that ions formed as later described will not reach the filament mesh **41**, the cathode shield **39** or the cathode **34**, but will be impelled to move in the other direction.

The multiple beam anode structure **43** as illustrated in detail in FIGURE 5 is framed by two end plates **57** and **58** which are preferably circular and both of which have holes **59, 61** of the same size and pattern as the holes of the other electrodes of the assembly **38** and in registry therewith. These two end plates **57, 58** are secured to each other in spaced coaxial alignment and with holes **59, 61** aligned by longitudinally extending circumferentially spaced tie rods **62** rigidly attached to the plates near their peripheries. A plurality of longitudinally extending wires **63** of a material such as tungsten are provided between the end plates **57, 58** in circumscribing relation to each set of the aligned holes **59, 61** respectively extending therethrough. The wires **63** thus define a plurality of communicating cells or beam defining tubes **64** (see FIGURE 6) which are effective in providing a multiple electron beam, i.e., a beam formed of a plurality of separate communicating beams, in the region between plates **57, 58**. As regards more particularly the structural details of the beam defining tubes **64** and wires **63** forming same, a plurality of small holes **66** are preferably provided through end plates **57, 58** in circumferentially spaced relation about each of the holes **59, 61** as best shown in FIGURE 6. A length of wire may then be threaded alternately back and forth through circumferentially successive ones of the holes 66 in end plates 57, 58. After threading the length of wire through a hole 66 to form the last wire 63 of a particular tube 64, the length of wire may then be threaded through the nearest one of the holes 66 circumscribing an adjacent one of the beam defining holes 59, 61 to start the formation of an adjacent tube 64. It has been found in practice that at least five wires 63 are required to suitably define each tube 64. To facilitate mounting of the multiple beam anode structure 43 in the multiple beam forming assembly 38, radially projecting mounting tabs 67 are secured to each of the rods 62 near the opposite ends thereof. The mounting tabs 67 when aligned with the mounting tabs of the other components of assembly 38, position the beam defining tubes 64 in a position of registry with the holes through the various electrodes 39, 41, 42.

The second ion trapping anode 44 of previous mention which is similar in construction to ion trapping anode 42 and is accordingly preferably formed as a cup is coaxially spaced from end plate 58 with its face distal with reference to the end plate. The plurality of holes 68 through the face of the anode 44 are axially aligned with the holes 61 of end plate 58 when the mounting tabs 69 of the ion trapping anode 44 are aligned with the tabs 67 of beam forming anode structure 43. The function of this ion trapping anode 44 is to aid in removing ions from the multiple beam anode structure 43 where they are formed and to aid in transmitting them into an accelerator as subsequently described in detail.

Following the ion trapping anode 44 in axially spaced alignment is the previously mentioned electron reflector grid 46 which is preferably comprised of a mounting ring 71 and a metal wire grid mesh 72 transversely secured therein and having at least 90% free area. Tabs 73 extending radially outward from ring 71 facilitate mounting of the grid in the assembly 38. This grid when appropriately biased serves to reflect the electrons of the multiple beams of electrons emerging from the plurality of holes 68 in the ion trapping anode 44 back through such holes and the beam defining cells formed by the axially aligned holes of the other electrodes of assembly 38 to filament mesh 41 whereat the electrons are again similarly reflected. The electrons are thus reflected back and forth or reflexed from the electron reflector grid 46 and the filament mesh 41 in each of the individual tubes 64. A uniform magnetic field parallel to the axis of tank 12 and the axes of tubes 64 is provided by means of axially spaced solenoids 74 concentrically disposed about the tank. The strength of this magnetic field may be 4000 gauss for instance, but may vary considerably from this amount to meet specific conditions. The presence of the magnetic field causes the electrons as reflected back and forth to follow rather tight spiral paths and in this way establishes an electron beam in each of the cells of the multiple beam anode structure 43.

Mounted mechanically as part of the multiple electron beam forming assembly 38 and following the electron reflector grid 46 is a cylindrical electrode 76 which in operation is a part of an ion accelertor assembly 77 disposed between assembly 38 and division member 21, which ion accelerator assembly is subsequently described in detail. The electrode 76 like the other elements structurally included in assembly 38 is provided with a plurality of radially extending mounting tabs 78 to facilitate mounting in the assembly.

Considering now preferred structure for mounting the various components hereinbefore described in the multiple beam forming assembly 38, axial tie rods 79 are inserted through the respective sets of registering mounting tabs of the cathode shield electrode 39, filament mesh electrode 41, ion trapping anode electrode 42, and proximal tabs 67 of multiple beam anode structure 43 while axial tie rods 81 are similarly inserted through the respective distal tabs of multiple beam anode structure 43, and registering sets of tabs of second ion trapping anode 44, electron reflector grid 46, and electrode 76. Tie rods 79 and 81 extend also through insulating spacers 82 disposed between each of the above-noted components of the assembly 38 to maintain same in the spaced coaxial relation described hereinbefore. The tie rods 79 are secured at one end to the proximal set of tabs 67 of the multiple beam anode structure 43 and at the other end to axially projecting brackets 83 which are spaced from the cathode shield electrode 39 by insulating spacers 84. The brackets 83 are attached to stand-off insulators 86 which are rigidly fastened to perforated support member 16 of tank 12. The tie rods 81 are similarly secured at one end to the distal set of tabs 67 of the multiple beam anode structure 43 and at the other end to elongated axially projecting brackets 87 which are secured to respective ones of the stand-off insulators 86. Compression springs 88 are best employed in the attachment of the brackets 87 to the tie rods 81 in order to allow for varying amounts of expansion and contraction of the various elements of the multiple beam forming assembly 38 during operation.

The ion accelerator assembly 77 which functionally but not structurally includes electrode 76 comprises a plurality of cylindrical ring electrodes 89 which are substantially similar to electrode 76 and respectively provided with radially projecting mounting tabs 91. The electrodes 89 are mounted in coaxially spaced relation by means of insulating spacers 92 disposed between the tabs 91 of axially successive ones of the electrodes. The assembly 77 is held in position at one end by an outwardly projecting annular flange 93 which is integrally formed as part of the last one of electrodes 89 and which for example may mount in a conformed recess 90 provided in the face of insulating member 26 of the division member 21 adjacent pumping region 18. The entire assembly 77 is held in compression by springs 94 secured between brackets 87 and the structurally first one of the electrodes 89, thus providing for expansion and contraction of the various parts by differing amounts as the temperature changes, e.g., as between periods of use and idleness.

Electrical potentials as required for operation of the ion pump 11 are applied to the various electrodes of the multiple beam forming assembly 38 and ion accelerating assembly 77 as through a corresponding plurality of terminals 96 only three of which are shown in FIGURE 1 for purposes of illustration. These terminals are of a construction which will withstand high vacuum and voltages to be used, such for instance, as the metal-ceramic Advac seal obtainable commercially. The terminals 96 are connected to suitable voltage supply means (not shown) so as to maintain the cathode shield electrode 39 at substantially the same potential as cathode 35, the filament mesh 41 at a relatively more positive potential than that of the cathode and cathode shield, the ion trapping anode 42 at a relatively more positive potential than that of the filament mesh, the multiple beam anode structure 43 at a slightly less positive potential than that of the ion trapping anode and more positive than the filament mesh, the second ion trapping anode 44 at substantially the same or a slightly lower potential than the first ion trapping anode 42 for instance 50 volts lower, and the reflector grid 46 at substantially the same potential as that of the cathode and cathode shield or slightly more negative than same. The electrodes 76, 89 of the ion accelerating assembly 77 are similarly energized to maintain uniformly negatively increasing potentials thereon in the direction of the division member 21.

The specific values of the foregoing potentials when the present invention is operated as an ion pump may vary over a considerable range; however, the following set of values is typical: The cathode 35 and cathode shield 39 are maintained at zero or ground potential, filament mesh **41** at +1000 volts, ion trapping anode **42** at +2100 volts and the electron reflector grid **46** at zero volts or slightly negative, possibly −100 volts, the ion accelerator electrodes **76, 89** may operate at −10,000 volts, −20,000 volts, −30,000 volts, −40,000 volts and −50,000 volts respectively in successive relationship.

As regards more particularly the exhaust region **19** of previous mention which receives ions from the pumping region **18** through the diaphragm **32** of partition member **21**, it is to be noted that a collector plate **97** is disposed within such exhaust region in coaxial spaced relation to the diaphragm **32**. The collector plate **97** is supported in such relationship as by means of a support member **98** which is attached to end plate **13** of tank **12**. Ions which penetrate the diaphragm **32** to enter exhaust region **19** hence impinge upon the collector plate **97** and are neutralized thereat to be converted to neutral gas molecules. The gas pressure within the exhaust region due to the neutral gas molecules is sufficient that the molecules may be efficiently removed by a conventional roughing vacuum pump. To facilitate this removal or exhaust of the gas molecules, the end plate **13** is preferably centrally apertured as at **99** and a communicating tube **101** is hermetically attached thereto for ready connection to a conventional pump (not shown) which need be capable of pumping to relatively low vacuum dimensions of the order of 1×10^{-5} millimeters of mercury.

In summary, the overall operation of the device physically described hereinbefore is as follows. The space **14** enclosed by vessel **15** and the communicating pumping region **18** within the tank **12** of pump **11** is first evacuated to approximately 10^{-7} millimeters of mercury by means of an oil diffusion pump operatively connected to port **17** of the vessel. The filament **37** is then energized to emit electrons from the face of cathode **35** into the pumping region **18** and operating bias is applied to the plurality of terminals **96** to energize the multiple beam forming assembly **38** and ion accelerating assembly **77** in the manner hereinbefore described, while solenoids **74** are energized to establish the uniform longitudinally extending magnetic field within the tank **12**. A portion of the electrons emitted from the cathode are attracted through the holes in the cathode shield electrode **39** towards the more positively charged filament mesh electrode **41** and such electrons bombard the wire mesh **51** disposed within the holes **49** thereof in axial registry with the holes of the cathode shield electrode. The wire mesh upon being heated by the bombarding electrons emits electrons in copious quantities. The electrons released by each individual loop of the filament mesh electrode **41** are in turn attracted longitudinally through the correspondingly aligned one of the holes of ion trapping anode **42** and into the respective axially aligned beam defining cells **64** of the multiple beam forming anode **43**. The electrons pass through such cells and in turn the registering holes of the second ion trapping anode **44** to reach the electron reflecting grid **46**. By virtue of the negatively increasing electric field provided in the direction of the reflecting grid **46**, the electrons are repelled therefrom back through the holes of the second ion trapping anode **44**, cells of the multiple beam forming anode **43**, holes of the first ion trapping anode **42**, to the filament mesh electrode **41**. The negatively increasing field in the direction of the cathode electrode **36** as established between the filament mesh electrode **41** and such cathode electrode is effective in reflecting the electrons therefrom. The travel of the electrons from the filament mesh electrode **41** to the reflecting grid **46** and return is, moreover, constrained by the uniform longitudinal magnetic field within the tank **12** which causes the electrons to travel in tight spiral paths through the individual tubes formed by the axially aligned holes and cells of the multiple beam forming assembly **38**. The magnetic field and electron accelerating electric field through the multiple beam forming assembly act as a converging lens tending to focus the reflexing beams in the individual tubes to separate concentrated pencils. It will be appreciated that it is this same focusing action in conventional single beam discharge devices which limits the maximum attainable effective cross-sectional area traversed by the beam. The present invention, however, by providing a plurality of transversely distributed tubes, provides for the formation of a separate electron beam in each tube with the spiral paths of the electrons being small enough in diameter to remain within individual ones of such tubes. This arrangement hence effectively spreads the beam over the entire area covered by all of the tubes.

The refluxing electrons in the multiple beam forming assembly, particularly the beam forming anode **43** thereof, hence bombard the remaining residual molecules within the pumping region **18** and those continuously randomly entering same from the vessel **15** over a materially greater active ionizing area than heretofore possible. The number of gas molecules which are bombarded and ionized in a given period of time is hence similarly increased as well as the number of electrons available for ionization. The ions formed upon collisions between the electrons and gas molecules within the individual tubes are in turn attracted through the electron reflector grid **46** in the direction of the ion accelerator assembly **77** by virtue of the negatively increasing field established in such direction. The ions are prevented from being attracted toward the cathode **34** by means of the slightly positively increasing field established between the beam forming anode **43** and first ion trapping anode **42**.

Upon entering the ion accelerator assembly **77** the negatively increasing potential therein accelerates the positive ions therethrough towards the partition member **21** and such ions are constrained by the magnetic field to form a central axial beam. The accelerated ion beam strikes the thin film central region **34** of the diaphragm **32** of division member **21** and penetrates same to enter the exhaust region **19** of vacuum tank **12**. Subsequent to entry into the exhaust region **19**, the ions impinge upon collector plate **97** and are neutralized to be reformed into neutral gas molecules. The relatively large proportion of gas molecules produced within the exhaust region are then removed through outlet tube **101** as by means of an operatively connected conventional vacuum pump (not shown) to produce an overall pumping action in the pumping region **18** and vessel **15** to be evacuated. Moreover, such pumping action in accordance with the ion pump **11** of the present invention establishes extremely high vacuum dimensions of the order of 10^{-10} millimeters of mercury or lower within the vessel **15** at pumping speeds estimated to be as high as 10^4 liters per second.

It will be appreciated that in initially reducing the pressure in pumping region **18** through the pumping port **17** of vessel **15**, care is taken to reduce the pressure in exhaust region **19** through tube **101** in approximately the same amount, since the central region **34** of diaphragm **32** is very thin and will not withstand great pressure differences on the two sides. From the initial start at atmospheric pressure, the pressure reduction in the two chambers may best be accomplished by connecting the outlets **17** and **101** to the same pump and pumping both spaces simultaneously. When the pressure in both regions **18** and **19** has been reduced to about 1×10^{-5} millimeters of mercury the two outlets should be transferred to separate pumps and space **21** together with space **14** further evacuated separately to about 10^{-7} millimeters of mercury prior to the start of operation of the ion pump.

In general the operation of the device herein described as an ion source follows closely the description of the ion pump operation. In order to operate the device as a source, it is only necessary to remove the end plate **13** and diaphragm **32** from the tank **12** and the entire tank **12** is removed from the vessel **15** and hermetically attached to a source of desirable ionizable gas. The now open end of the tank 12 may then be attached in vacuum sealed relation to an accelerator or other ion utilizing apparatus. In this event vacuum is maintained in tank 12 through the vacuum system of the apparatus for which ions are to be provided. Ions as generated in the multiple beam forming assembly 38 and accelerated in the ion accelerator 77 are thus accelerated directly into the apparatus where they are to be used.

Although the present invention has been disclosed in a single preferred embodiment it will be evident to those skilled in the art that many variations are possible within the spirit of the invention. Therefore it is not intended to limit the invention except as defined by the following claims.

What is claimed is:

1. A gaseous discharge device comprising a vacuum tank enclosing a low pressure region, means carried by said tank for generating a uniform magnetic field axially thereof, electron emitter means disposed within said tank for introducing electrons thereto, a multiple electron beam forming assembly disposed coaxially within said tank and receiving the electrons from said electron emitter means, said assembly coacting with said magnetic field to form said electrons into a plurality of transversely communicating separately defined reflexing electron beams extending longitudinally of the tank, said electron beams ionizing gaseous molecules within the tank to form ions and additional electrons, and means disposed within said tank for withdrawing ions from the region of the reflexing electron beams.

2. A gaseous discharge device as defined by claim 1, further defined by neutralizing means disposed within said tank in receiving relation to the ions withdrawn from the reflexing electron multiple beam region to neutralize the ions whereby said ions may be pumped from the tank in the form of neutral gas molecules.

3. An ion pump comprising an evacuated housing having an inlet for admitting gaseous molecules thereto, means carried by the housing for producing an axially parallel magnetic field therethrough, an electron gun coaxially mounted in an end of said housing to produce an electron flux, a multiple electron beam forming assembly mounted in adjacent coaxially spaced relationship with said electron gun, said beam forming assembly having means for multiplying the electrons impinging thereon from said electron gun and forming the resulting multiplicity of electrons into a plurality of axially parallel transversely communicating refluxing electron beams, said electron beams producing ions from gas molecules within said housing, an ion accelerator coaxially spaced from said multiple electron beam forming assembly and having means for accelerating said ions axially through said housing, a transverse diaphragm hermetically secured within said housing following said ion accelerator and pervious to the accelerated ions therefrom so that said accelerated ions penetrate therethrough, an ion receiver disposed coaxially adjacent said diaphragm on the distal side thereof relative to said ion accelerator for receiving the penetrating ions and converting same to gas molecules, and means communicating with said housing in the region of said ion receiver for removing said gas molecules from said housing.

4. An ion source comprising a vacuum tank enclosing a low pressure region, said tank having an inlet at one end for admitting ionizable gas to the low pressure region and an axial ion egress opening at the other end, means carried by said tank for producing a uniform longitudinally extending magnetic field therethrough, an electron source disposed at the inlet end of said tank for directing electrons thereinto, a multiple electron beam forming assembly disposed coaxially within said housing following said electron source and receiving the electrons therefrom, said multiple beam forming assembly coacting with said magnetic field to form said electrons into a plurality of axially parallel transversely communicating reflexing electron beams, said electron beams ionizing gas within said housing to form ions and additional electrons, and ion accelerating means disposed coaxially within said vacuum tank between said multiple beam forming assembly and said ion egress opening to accelerate said ions therethrough.

5. A multiple beam gaseous discharge device comprising a vacuum tank enclosing a low pressure region and having means for admitting gas thereto, magnet means carried by said tank for generating a uniform longitudinal magnetic field therethrough, a source of electrons disposed at one end of said tank, a filament mesh electrode coaxially spaced from said source transverse to said magnetic field and having a plurality of axial holes therethrough with filamentary thermionic emissive mesh covering same, means directing electrons from said source through the holes of said filament mesh electrode, said electrons thereby impinging upon the thermionic emissive mesh and effecting emission of a multipled quantity of electrons therefrom through said holes, a multiple beam anode coaxially disposed within said tank following said filament mesh electrode and having a plurality of axially parallel transversely communicating beam defining tubes in respective registry with the holes of said filament mesh electrode, a grid coaxially disposed within said tank following said multiple beam forming anode, means for establishing an electric field within said tank negatively increasing axially on opposite sides of said multiple beam forming anode in the directions of said filament mesh electrode and said grid respectively, an ion accelerator coaxially disposed within said tank following said grid for establishing a negatively increasing ion accelerating field axially away from said grid, and means for discharging ions from the tank.

6. A multiple beam gaseous discharge device as defined by claim 5, further defined by said means for discharging ions having an element receiving and neutralizing said ions whereby said ions may be pumped from said tank in gaseous form.

7. A multiple beam gaseous discharge device as defined by claim 5 but wherein said multiple beam anode comprises a pair of end plates secured in coaxially spaced relation and respectively having pluralities of holes in axial registry with the holes of said filament mesh electrode, and a plurality of longitudinally extending wires secured between said end plates and circumferentially spaced about each set of registering holes thereof to thereby form said beam defining tubes.

8. A multiple beam ion pump comprising a vacuum tank, said tank having an accelerated ion pervious partition dividing the tank into a pumping region and an exhaust region hermetically sealed from each other, said tank having inlet means communicating with said pumping region for admitting gas thereto from a region to be evacuated and outlet means communicating with said exhaust region for exhausting gas therefrom, magnet means carried by said tank for generating a uniform magnetic field extending longitudinally therethrough, a source of electrons disposed within said pumping region at the distal end thereof relative to said partition, a filament mesh electrode coaxially spaced from said source and having a plurality of axial holes covered by thermionic emissive mesh, means directing electrons from said source through the holes of said filament mesh electrode, a multiple beam anode coaxially disposed within said pumping region following said filament mesh electrode and having a plurality of axially parallel transversely communicating beam defining tubes in respective registry with the holes of said filament mesh electrode, a grid coaxially disposed within said tank following said multiple beam forming anode, means for establishing an axial electric field within said pumping region negatively increasing in opposite directions from said anode to said filament mesh electrode and to said grid respectively, an ion accelerator coaxially dis-

posed within said pumping region between said grid and said partition for establishing an axial negatively increasing ion accelerating field in the direction of the partition, and an ion receiver disposed within said exhaust region in coaxially spaced relation to said partition for neutralizing ions and thereby forming neutral gas molecules.

9. A multiple beam ion pump as defined by claim 8, further defined by said multiple beam anode comprising a pair of end plates mounted in coaxially spaced relation and respectively having pluralities of holes in axial registry with the holes of said filament mesh electrode, and a plurality of longitudinally extending wires secured between said end plates and circumferentially spaced about each set of registering holes thereof to thereby form said beam defining tubes.

10. A multiple beam gaseous discharge device comprising a vacuum tank enclosing a low pressure region and having an inlet for admitting gas thereto, magnet means carried by said tank for generating a uniform magnetic field extending longitudinally therethrough, an electron emissive cathode disposed at one end of said tank in coaxial relation to said magnetic field, a cathode shield electrode having a plurality of uniformly transversely distributed holes therethrough and coaxially spaced from said cathode, a filament mesh electrode coaxially spaced from said cathode shield electrode and having a plurality of holes covered by thermionic emissive mesh in axial registry with the holes of said cathode shield electrode, an ion trapping anode coaxially spaced from said filament mesh electrode and having a plurality of holes in axial registry with the holes of the filament mesh electrode, a pair of beam forming anode plates mounted in coaxially spaced realtion with the first plate following said ion trapping anode, said plates respectively having holes in axial registry with the holes of the ion trapping anode, a plurality of longitudinally extending wires secured between said plates and circumferentially spaced about each set of registering holes thereof, a second ion trapping anode coaxially following the second beam forming anode plate and having a plurality of holes in axial registry with the holes of said plate, a grid disposed in coaxially spaced relation from said second ion trapping anode, a plurality of coaxially spaced apart ion accelerating electrodes following said grid, means for applying operating potential to said cathode, cathode shield electrode, filament mesh electrode, ion trapping anodes, beam forming anode plates, grid, and ion accelerating electrodes to maintain the cathode, cathode shield electrode and grid at the same potential, the filament mesh electrode at a more positive potential than said cathode, cathode shield electrode and grid, the ion trapping anodes at a more positive potential than the filament mesh electrode, the beam forming anode plates at a potential intermediate the potentials of said filament mesh electrode and ion trapping anodes, and the ion accelerating electrodes at progressively negatively increasing potentials relative to the potential of said grid, and means for receiving ions from said ion accelerating electrodes and discharging same from said tank.

11. A multiple beam ion pump comprising a vacuum tank, an accelerated ion pervious diaphragm hermetically mounted transversely within said tank and partitioning same into a pumping region and an exhaust region pressure sealed therefrom, inlet means communicating with said pumping region for admitting gas thereto from a region to be evacuated, outlet means communicating with said exhaust region for discharging gas therefrom, magnet means carried by said tank for generating a uniform magnetic field extending longitudinally therethrough, an electron emissive cathode disposed at the distal end of said pumping region relative to said diaphragm in coaxial relation to said magnetic field, a cathode shield electrode having a plurality of uniformly transversely distributed holes therethrough and coaxially spaced from said cathode in said pumping region, a filament mesh electrode coaxially spaced from said cathode shield electrode and having a plurality of holes covered by thermionic emissive mesh in axial registry with the holes of said cathode shield electrode, an ion trapping anode coaxially spaced from said filament mesh electrode and having a plurality of holes in axial registry with the holes of the filament mesh electrode, a pair of beam forming anode end plates mounted in coaxially spaced relation with the first plate following said ion trapping anode, said plates respectively having holes in axial registry with the holes of the ion trapping anode, a plurality of longitudinally extending wires secured between said plates and circumferentially spaced about each set of registering holes thereof, a second ion trapping anode coaxially following the second beam forming anode plate and having a plurality of holes in axial registry with the holes of said plate, an electron reflector grid disposed in coaxially spaced relation from said second ion trapping anode, a plurality of coaxially spaced apart ion accelerating electrodes disposed between said grid and said diaphragm, potential supply means for maintaining said cathode, cathode shield electrode and grid at the same potential, said filament mesh electrode at a more positive potential than said cathode, cathode shield electrode, and grid, said ion trapping anodes at a more positive potential than the filament mesh electrode, said beam forming anode plates at a potential intermediate the potentials of said filament mesh electrode and ion trapping anodes, and the ion accelerating electrodes at progressively negatively increasing potentials relative to the potential of said grid, and an ion receiver disposed within said exhaust region and coaxially spaced from said diaphragm to neutralize ions and thereby form neutral gas molecules.

No references cited.