May 12, 1942. C. W. HANSELL 2,282,401

ELECTRICAL VACUUM PUMP

Original Filed Jan. 6, 1938 2 Sheets-Sheet 1

Fig. 1

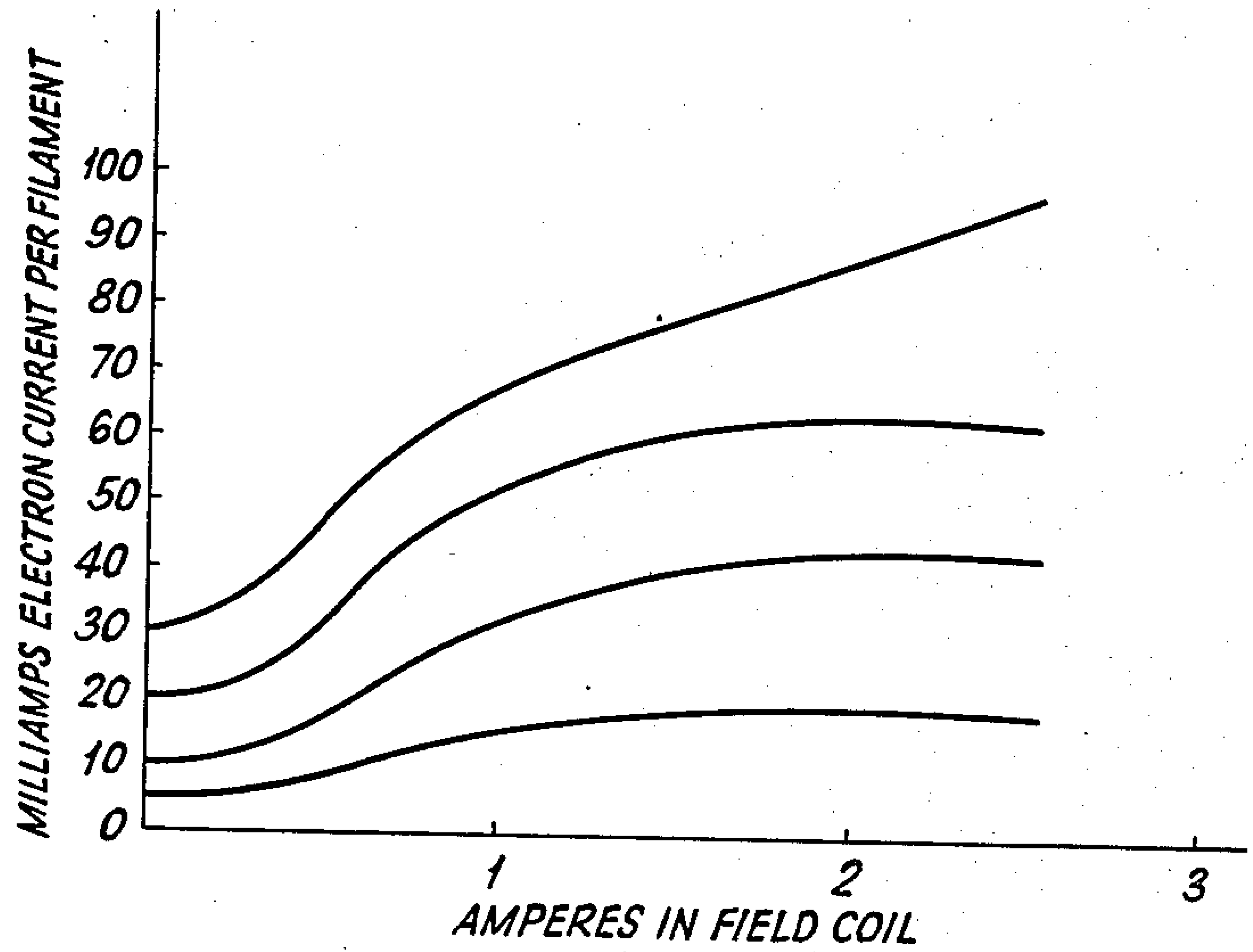
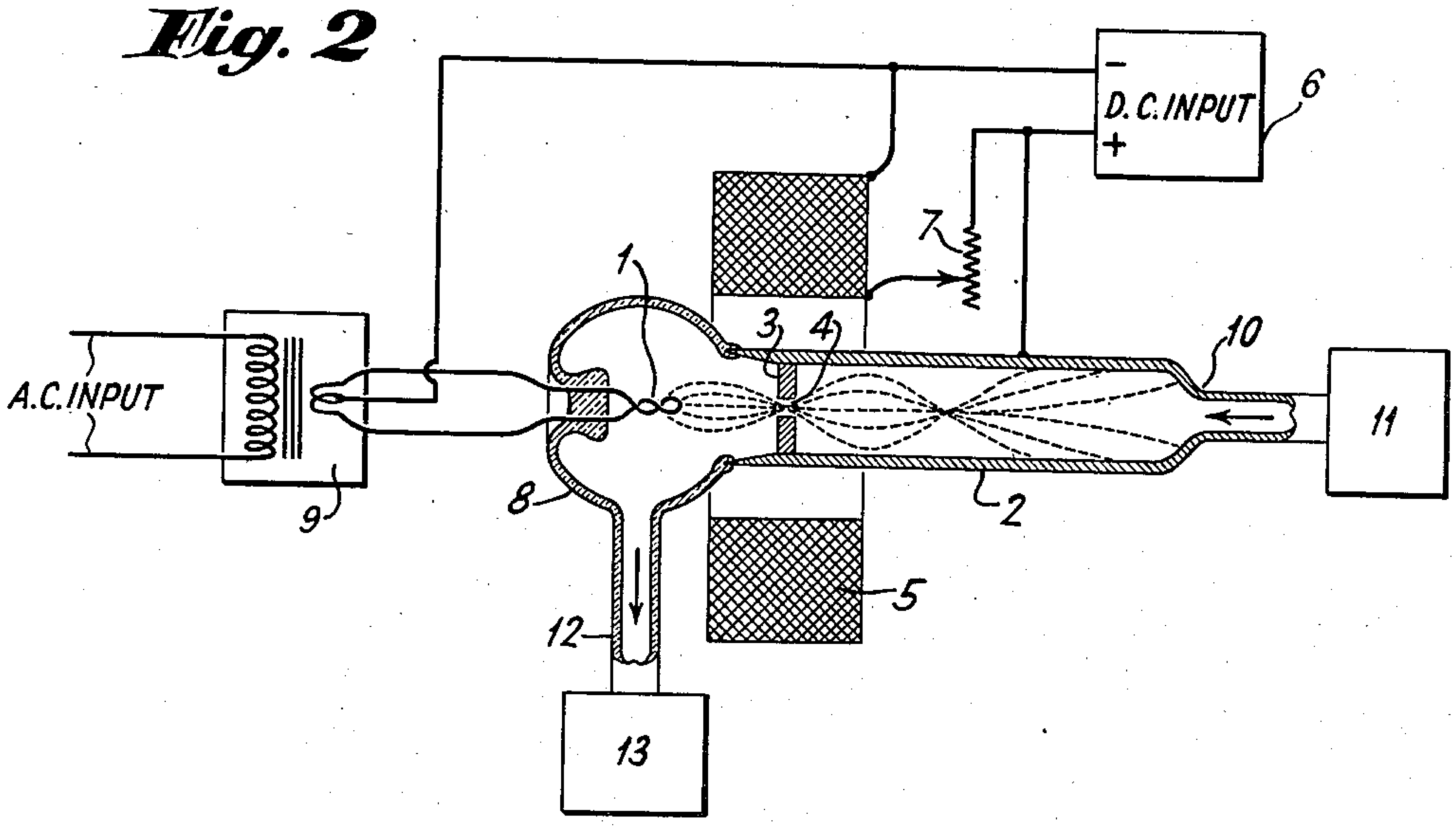


Fig. 2



INVENTOR.
C. W. HANSELL

BY H. S. Grover

ATTORNEY.

May 12, 1942. C. W. HANSELL 2,282,401

ELECTRICAL VACUUM PUMP

Original Filed Jan. 6, 1938 2 Sheets-Sheet 2

Fig. 3

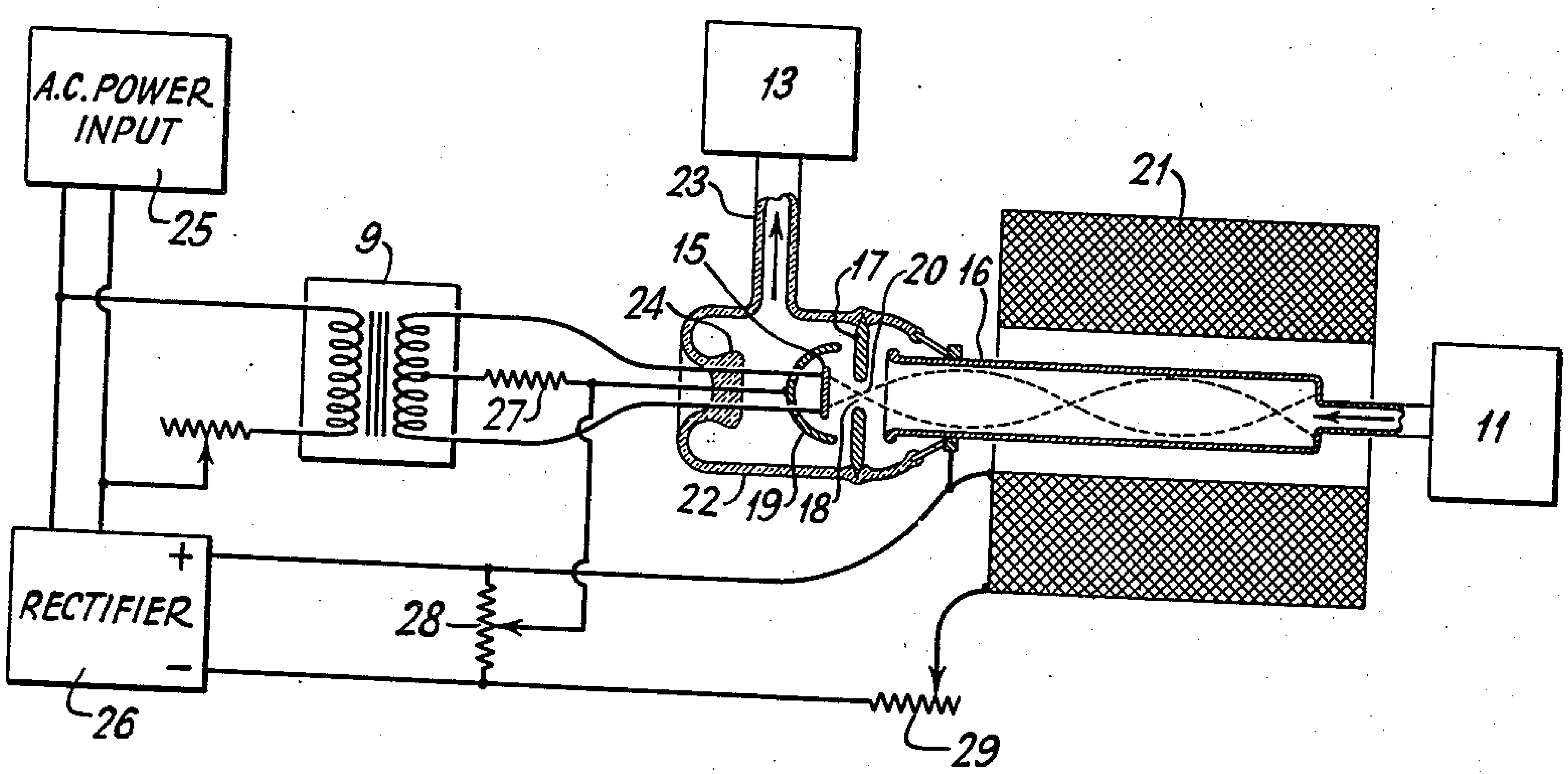
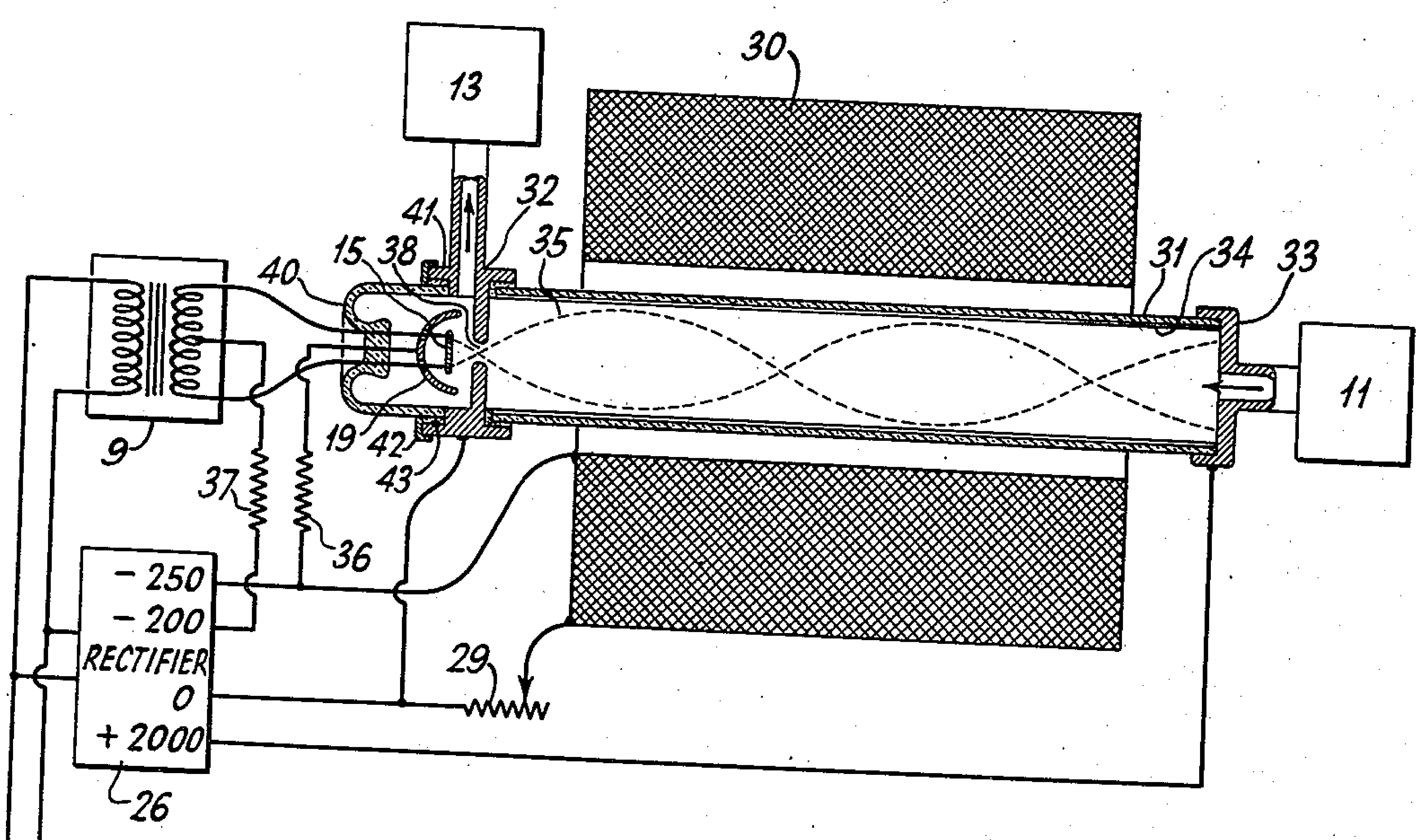


Fig. 4



INVENTOR.
C. W. HANSELL

BY H. S. Grover

ATTORNEY.

Patented May 12, 1942

2,282,401

UNITED STATES PATENT OFFICE

2,282,401

ELECTRICAL VACUUM PUMP

Clarence W. Hansell, Port Jefferson, N. Y., assignor to Radio Corporation of America, a corporation of Delaware

Application January 6, 1938, Serial No. 183,584
Renewed January 30, 1940

19 Claims. (Cl. 230—69)

This invention relates to a new and novel improved electrical vacuum pump and is a further improvement in the electrical vacuum pump of the type described in my United States Patent #2,022,465, granted Nov. 26, 1935.

An object of this invention is to further improve electrical vacuum pumps by the addition of a magnetic field which is so arranged in conjunction with the vacuum pump that the electron paths are brought closer together and lengthened out, which results in increasing the speed of the pumping action and increasing the final obtainable vacuum.

A feature of this invention resides in the arrangement of an electron discharge tube within a field coil so that a magnetic field is established through the tube with the lines of magnetic force substantially parallel to the axis of the tube.

Another feature of this invention is the focusing of the electron stream within the electron discharge tube, resulting in a further increase in the pumping action, as will be explained more fully later.

I have found that, by the use of a magnetic field through a rather long electron discharge tube, the length of electron paths between the filament and anode can be increased. The increase in electron paths length is obtained because the magnetic field tends to restrict the paths to make them more nearly parallel to the axis of the tube so that electrons can, on the average, travel a much greater distance along the tube before striking the tube wall. Electrons normally tend to take paths spreading out more or less in all directions from the source so that the electron motions have components at right angles to the axis of the tubes. Addition of the magnetic field tends to cause deflecting or bending of the motions at right angles to the axis, making the electrons follow helical paths parallel to the axis.

The application of a magnetic field gives many of the electrons a longer spiraled path and therefore the probability for collision with gas molecules is greatly increased. This causes an increase in ionization with a resultant increased pumping effect for a given value of cathode electron emission current. At the same time, the final obtainable degree of vacuum for a given current, is increased because of the increased ratio of mean electron path to mean electron free path in the gas. Each electron, since it can travel over a longer path, has a greater probability of collision with a molecule. For example, at one micron pressure in air, the mean free path of an electron has been determined to be about sixty-five centimeters, or twenty-five inches. I have also found that by placing a metallic shield having a central hole and locating the shield between the cathode and anode and applying a magnetic field with flux lines parallel to the axis of the pump or tube, those electrons which leave the cathode in undesired directions, away from the axis, may be made to return to the vicinity of the axis, or to describe more or less helical paths passing through the hole in the shield. In practice, the shield may be connected to, or form a part of the anode in which case after entering the anode, the electrons continue to follow helical paths until they get to a region of decreased magnetic field which then allows them to land upon the surface of the anode.

This invention will best be understood by referring to the accompanying drawings, in which:

Fig. 1 is a curve showing some experimentally determined characteristics indicating an increase in current flowing between an anode and cathode of a tube when the tube was placed in the presence of a variable magnetic field which increased the length of electron paths.

Fig. 2 is a simple form of this invention.

Fig. 3 is another embodiment of this invention; and

Fig. 4 is a still further improvement of the embodiment shown in Figs. 2 and 3.

Referring now in detail to the drawings, it will be noted that in the curves shown in Fig. 1, as the current is increased in the field coil there is produced a corresponding increase in magnetic field, the electron current increases as a result of increased ionization which lowers the space charge voltage drop and increases the cathode emission.

Fig. 2 shows one form of electrical vacuum pump which makes use of a magnetic field. It consists of a cathode **1** and an anode **2**, both of which are so arranged that when electron current flows between them in the presence of gas, the gas will be ionized and move toward the cathode in a manner to pump the gas out of a chamber to be evacuated. The anode consists preferably of a metal tube, which is closed at one end by a metallic shield **3** having a small aperture **4** of moderate dimensions, for example, 0.01 to 0.5 centimeter diameter, depending upon the available electron emission current from the cathode. Surrounding anode **2** and shield **3** is a magnetic field coil **5** which is electrically connected to a direct current input source **6**. A field rheostat **7** is connected in series between the direct current input and the field coil 5 to vary the magnetizing current and strength of the magnetic field. At one end of the tubular anode, there is located a glass envelope 8 to which the metallic anode is sealed at a point adjacent the field coil 5. Cathode 1 is supported substantially centrally with respect to the axis of the field coil and faces aperture 4. Cathode 1 is heated by an alternating current input source in the form of a transformer 9, the center point of the secondary of which is connected to the minus side of the direct current input 6, the positive side of the direct current input being connected to anode 2. The far end of the tube forming the anode is tapered at a point 10 to receive the outlet from the object 11 to be pumped or evacuated. The lower portion 12 of envelope 8 is arranged for connection to an outlet which makes fluid connection with rough vacuum pump 13.

In the modification shown in Fig. 3, a hot cathode or heavy filament 15 is mounted symmetrically with respect to the axis of an anode 16 which is in the form of a long thin metallic tube. Interposed between cathode 15 and anode 16 is a metallic diaphragm or ring-like member 17 having an aperture 18. Directly behind cathode 15 is arranged a negatively charged shield 19 which with aid of a magnetic field, tends to focus the electron emission of the cathode upon the aperture 18. The cathode, which is preferably in the form of a ring around the axis of the hole in the diaphragm, gives a cone-like path of electron emission focused upon the aperture, and this emission tends to diverge after passing through the aperture, as is indicated by the broken lines 20. However, when an axial magnetic field is applied, by passing current through the field coil 21, which aids the focusing action and limits the divergence of the electron emission after it is passed through the aperture 18, due to the magnetic field and the initial radial component of velocity, each electron is made to follow a helical path after passing through the hole in the anode diaphragm. This helical path of each electron tends to pass through the axis of the system at frequency intervals and the total length of the path may be many times greater than would be obtained without the application of the magnetic field. The electron paths all tend to come together at the same points where each path passes through the axis of the tube. Although there is shown only one diaphragm, it is possible to place additional diaphragms with holes through their centers at each electron focusing point in order to increase the pumping action. Other structural members of this improved electrical vacuum pump comprise envelope 22 having a stem 23 for connection to rough pump 13, and a stem or press 24 for supporting shield 19 and filament 15, filament 15 being heated from an alternating current power source 25, which is connected to transformer 9 and rectifier 26. The secondary central connection of transformer 9 is connected to shield 19 through a resistance 27, also, a variable negative potential is applied to shield 19 by means of a variable resistance 28. The positive side of the rectifier is connected directly to anode 16 and one side of the winding of field coil 21, the negative side of the rectifier being connected in series with a variable resistance 29.

A preferred embodiment of this invention is shown in Fig. 4, which consists of a field coil 30 surrounding a long insulating tube 31 which is electrically connected to and extends from a first diaphragm anode 32 to a second anode 33 which is maintained at a much higher direct current potential than anode 32. Insulating tube 31 is lined with a very thin layer of high resistance conducting material 34, which is similar to material employed in some of the so-called "metallized resistors." Due to the high resistance conducting material 34, a substantially uniform electric field is maintained within the long tube 31. This field tends to lengthen the electron paths 35 and increase the electron velocities. In addition, it also causes all ions formed by collision of the electrons and molecules to move toward the cathode. There is a further advantage in employing the long tube with a potential gradient throughout its length, in that secondary electrons produced by collision of primary electrons and molecules of gas with the conducting material lining the tube are accelerated toward anode 33 and are caused to add to the production of the ionization of any gas in the tube. To reduce the bombardment of the cathode and protect it from the effect of occasional arcs, there are provided resistance elements 36 and 37 through which emission current from the cathode must pass. These resistances should be high enough to limit the cathode emission current to safe values or to values below the available electron emission from the cathode 15. In addition to the detail shape and arrangement of the cathode, a shield 19 and and first anode orifice 38 are provided to reduce the tendency for ions to strike the cathode and to make them strike the shield instead. This shield is made with substantial mass and heat radiation to withstand bombardment. However, in order to more fully protect the tube and circuit, the resistance 36 is connected in series with the shield and the negative side of the rectifier unit 26, so that a limited amount of current can flow through it. However, resistance 36 should be considerably smaller in value than resistor 37, which is connected in the cathode circuit. The envelope 40 is arranged on the metal anode structure 32 in such a manner that this portion of the pump on which the cathode and shield are held may be interchangeable, so as to furnish new elements as required, by providing a flange 41, metallic band clamp 42, and gasketed joint 43, which may be in the form of a mercury seal, a low melting point fusable alloy seal such as for example woods metal, or the like. Such an arrangement greatly facilitates cathode renewals, particularly since the joints are really a part of the rough pump system, rather than the high vacuum system.

In the operation of this invention, a fair degree of vacuum is maintained in the system by means of rough pump 13. The cathode is then heated up to a temperature which causes electrons to be emitted and then the direct current potential is applied to the anode elements and the magnetic field is built up to a value in which the electron paths are suitably lengthened focused to give the maximum pumping effect. When the pump is started, the initial stage of pumping may be shortened by connecting some or all of the elements of the tube to be exhausted to a source of high positive direct current potential or direct current and alternating current superimposed which is high enough to cause a direct current discharge from the elements of the tube to the electrodes of the pump. Naturally, the tube to be exhausted should be heated during evacuation in the usual manner. A pump of the type described has many advantages not possessed by other types of vacuum pumps, such as the Langmuir vapor jet-condensation pump, which requires low temperature traps to keep vapors out of the vessel which is to be exhausted.

Although only a few embodiments of this invention have been shown, it is to be distinctly understood that it should not be limited to the arrangement illustrated.

What is claimed is:

1. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a metallic anode adjacent said cathode, a second anode spaced apart from said first anode, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

2. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a metallic anode adjacent said cathode, a second anode spaced apart from said first anode by an insulating tube, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

3. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a metallic anode adjacent said cathode, a second anode spaced apart from said first mentioned anode by an insulating tube, a thin layer of high resistance conductive material within said insulating tube, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

4. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a metallic anode adjacent said cathode, a removable support member for said cathode, a second anode spaced apart from said first anode, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

5. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a metallic anode adjacent said cathode, a second anode spaced apart from said first anode by an insulating tube, means adjacent said first mentioned anode for removing said cathode, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

6. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a shield in the rear of said cathode, a metallic anode adjacent said cathode, a second anode spaced apart from said first anode, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

7. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode centrally located at one end of said electron discharge device, a metallic anode adjacent said cathode, a second anode spaced apart from said first anode, a central aperture in both of said anodes, means for supplying a voltage substantially higher to said second anode than to said first anode, and magnetic means interposed between said anodes for producing a magnetic field for increasing the length of the electron path in said electron discharge device.

8. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with an object to be evacuated, an outlet, a cathode located at one end of said electron discharge device, a metallic anode adjacent said cathode, a second anode spaced apart from said first anode, a magnetic field coil located between both of said anodes, an alternating current supply source connected to said cathode, a rectifier connected to said alternating current source for supplying direct current to said field coil, and a variable resistance in series with said rectifier and said field coil for varying the current therethrough, and means for varying the magnetic flux in said field coil to increase the length of the electron path in said electron discharge device.

9. An electron vacuum pump comprising an electron discharge device having an inlet associated with the object to be evacuated, and an outlet, a cathode located at one end of said device, a shield in the rear of said cathode, an anode located adjacent said cathode, said anode having a portion of reduced diameter at the end away from said cathode, a metallic diaphragm having an aperture within said device, said diaphragm being located intermediate said cathode and said anode, and means between said inlet and said outlet for producing a magnetic field to lengthen the electron path between said cathode and said anode.

10. An electron vacuum pump comprising an electron discharge device having an inlet associated with the object to be evacuated, and an outlet, a cathode located at one end of said device, a tube-like anode located at the other end of said device, and a magnetic field coil surrounding said anode for producing a magnetic field to lengthen the electron path between said cathode and said anode.

11. An electron vacuum pump comprising an electron discharge device having an inlet associated with the object to be evacuated, and an outlet, a cathode located at one end of said device, an anode in the form of a long metallic tube

located at the other end of said device, and means surrounding said anode for producing a magnetic field to lengthen the electron path between said cathode and said anode.

12. An electrical vacuum pump comprising an electron discharge device having an inlet associated with the object to be evacuated, and an outlet, an insulating tube, a cathode centrally located at one end of said device, an anode located at each end of said insulating tube, a removable support member for said cathode, and means surrounding said insulating tube for producing a magnetic field to lengthen the electron path between said cathode and at least one of said anodes.

13. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with the device to be evacuated, and an outlet, an anode and a cathode, a magnetic field coil surrounding the anode of said electron discharge device, an alternating current input supply source connected to said cathode, a direct current source connected to said anode and a midpoint of potential on said cathode and one side of said field coil, and variable means connected to the other side of said field coil and to said direct current source for varying the magnetic flux in the coil surrounding said anode.

14. Vacuum producing apparatus comprising in combination an electron discharge device having an inlet associated with the device to be evacuated, and an outlet, an anode and a cathode, a magnetic field coil located between said anode and said cathode, an alternating current supply source connected to said cathode, a rectifier having its input connected to said alternating current source and its output connected to said field coil for supplying direct current thereto, a variable resistance connected in series with one side of said rectifier and said field coil for varying the current thereto, and a connection between said field coil and a point of mid-potential and said cathode.

15. An electron vacuum pump comprising an electron discharge device having an inlet associated with the device to be evacuated, and an outlet, at least an anode and a cathode, said cathode located at one end of said device, said anode located at the other end of said device, means adjacent said anode for producing a magnetic field to lengthen the electron path with the said anode, a mechanical pump, and means including a first and a second aperture in said device for fluid communication with said electron discharge device and said mechanical pump.

16. An electrical pump comprising an electron discharge device having an inlet associated with the device to be evacuated, and an outlet, a cathode located at one end of said device, a long tube-like anode, a metallic shield having an aperture therein and located within said tube-like anode, means for passing electrons through the aperture in said shield in one direction and ions and molecules of gas through the aperture of said shield in the opposite direction, and a magnetic field surrounding said tube-like anode for increasing the efficiency of said pump.

17. An electrical vacuum pump comprising an electron discharge device having an inlet associated with the device to be evacuated, and an outlet, a cathode located at one end of said electron discharge device, an anode intermediate said inlet and said outlet, a shield located intermediate said cathode and said anode, and means located between said inlet and said shield for producing a magnetic field to increase the pumping speed of said device.

18. An electrical vacuum pump comprising an electron discharge device having an inlet associated with the device to be evacuated, and an outlet, a cathode located at one end of said electron discharge device, an anode intermediate said inlet and said outlet, a shield located intermediate said cathode and said anode, a tube which is relatively long with respect to its width located between said inlet and outlet, and means surrounding said tube for producing a magnetic field to increase the pumping speed of said device.

19. An electrical pump comprising an electron discharge device having an inlet associated with an object to be evacuated, and an outlet, a cathode located at one end of said device, an anode intermediate said inlet and said outlet, a magnetic disc serving as a shield and located intermediate said cathode and said anode, means including an aperture located in said shield for passing electrons therethrough in one direction and ions and molecules of gas through the aperture in the opposite direction, and a magnetic field adjacent said anode for increasing the efficiency of said pump.

CLARENCE W. HANSELL.