Nov. 26, 1935. C. W. HANSELL 2,022,465
ELECTRICAL VACUUM PUMP
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Fig. 1

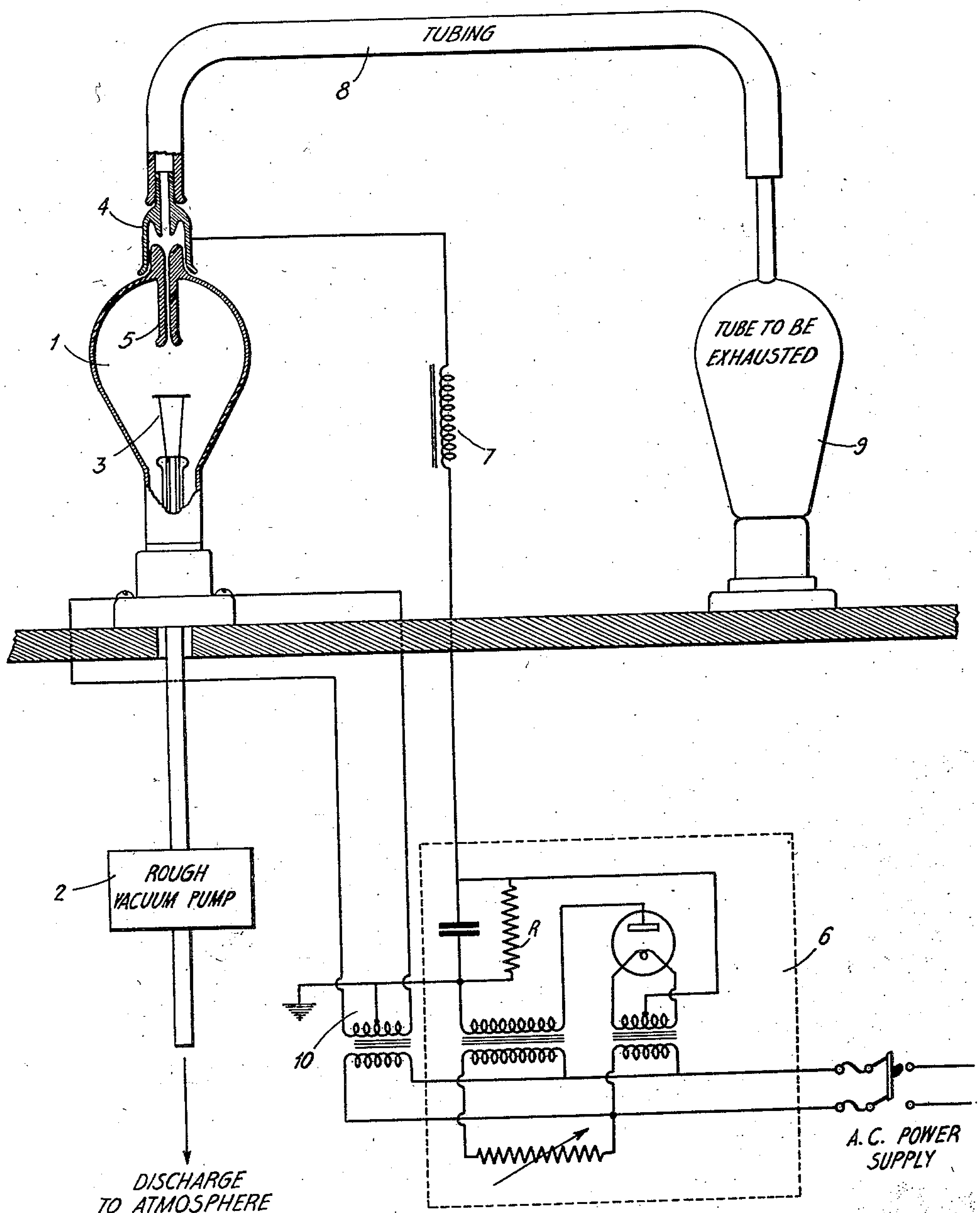

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Fig. 2

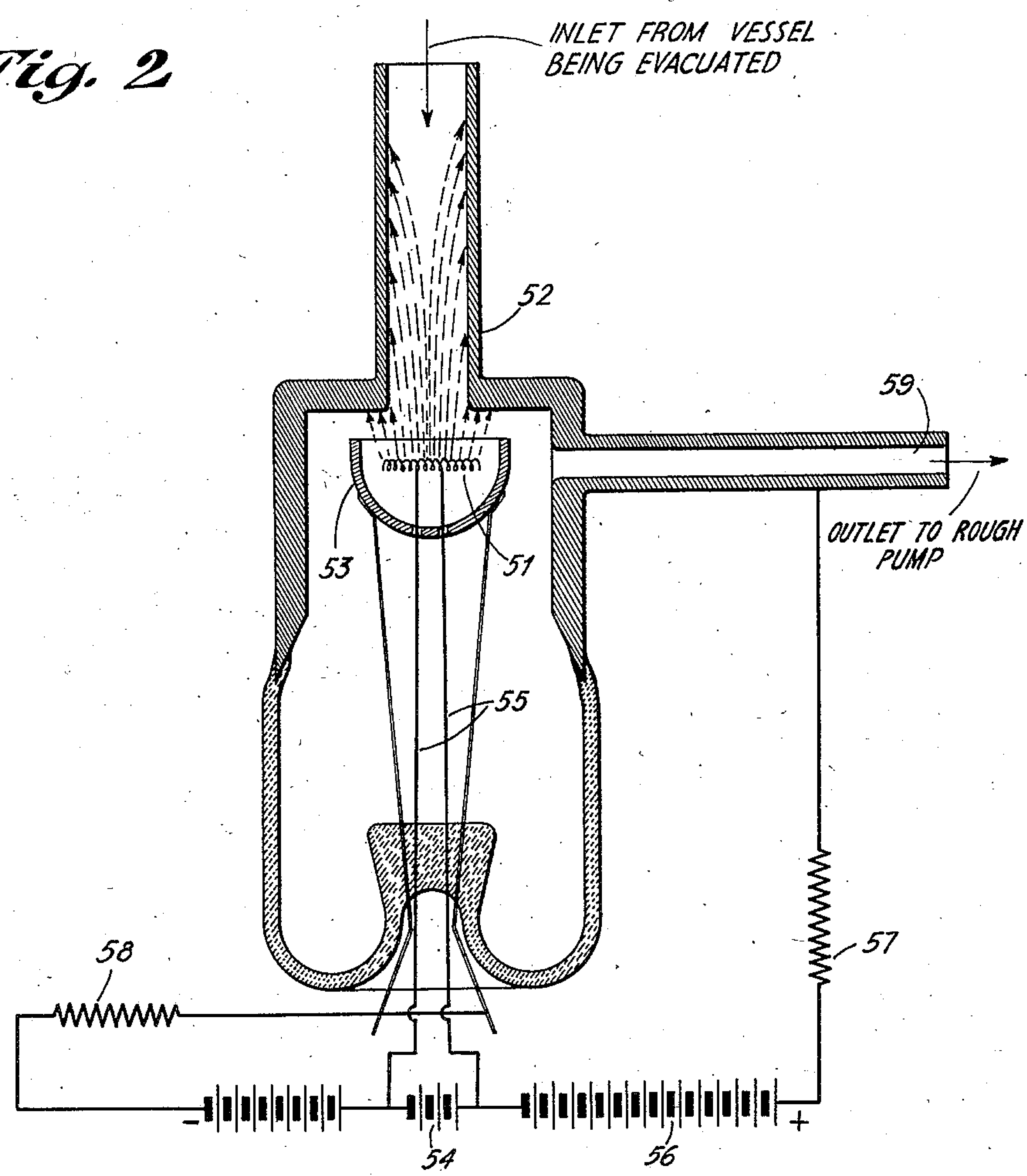

Fig. 6

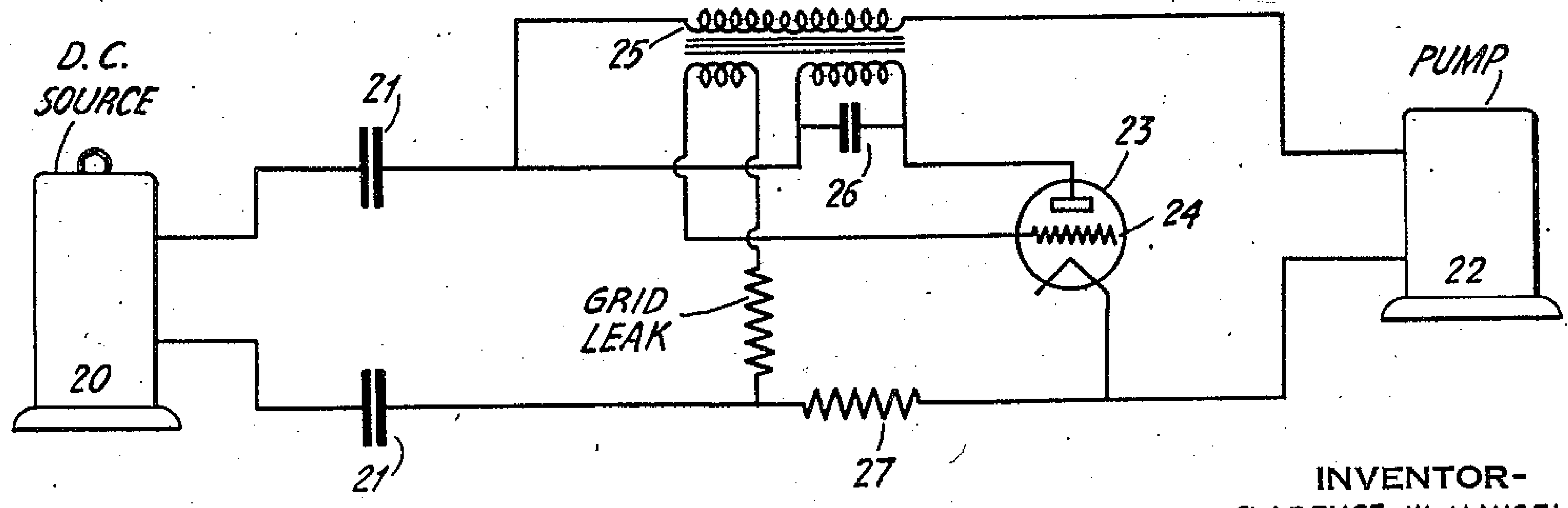

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Fig. 3

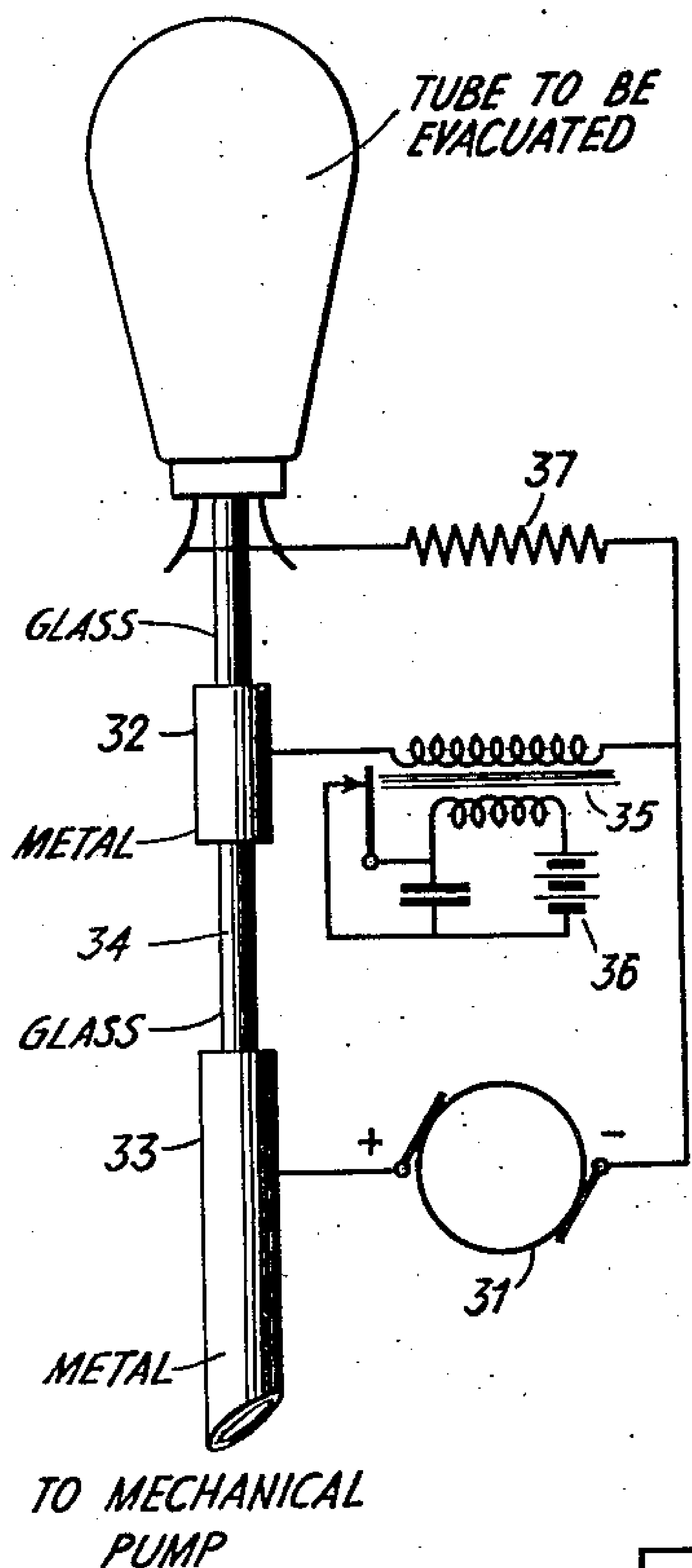

Fig. 4

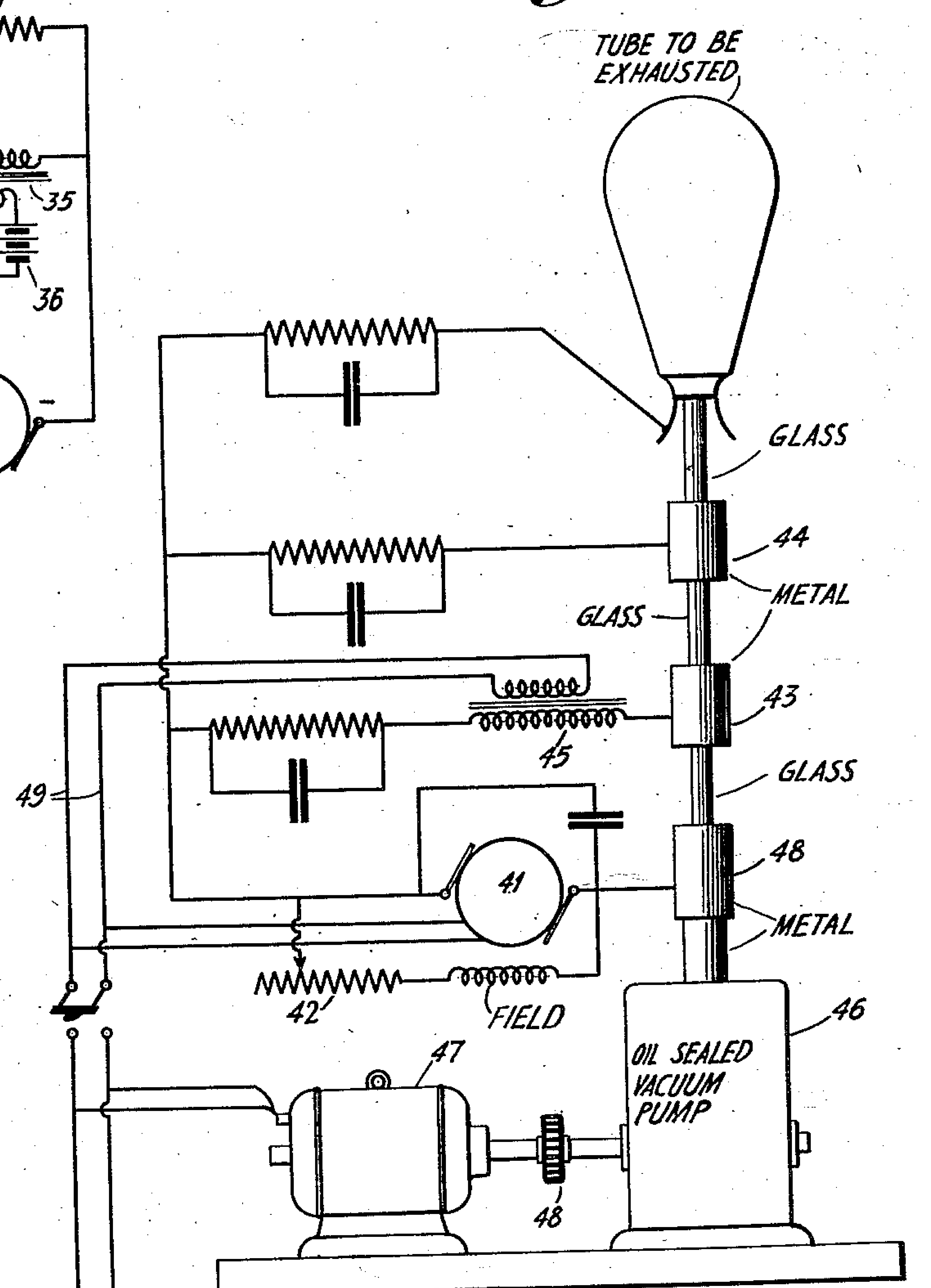

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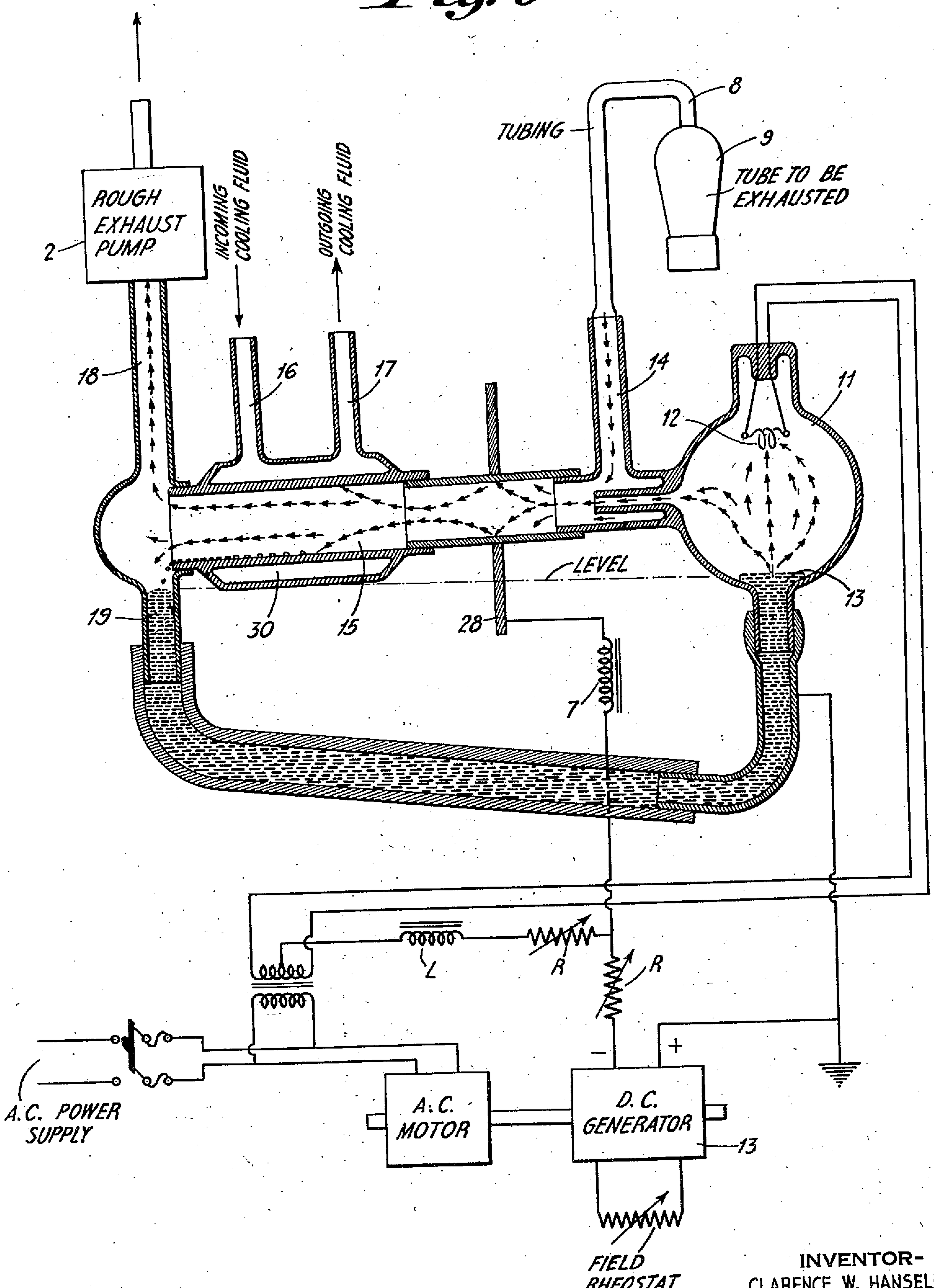
Fig. 5



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2,022,465

ELECTRICAL VACUUM PUMP

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Application December 14, 1932, Serial No. 647,189

12 Claims. (Cl. 230—69)

This invention relates to apparatus for producing high vacua in closed receptacles, such as bulbs, electron discharge devices and the like, and has for its object to provide a simplified and improved type of vacuum pump.

In present day evacuation processes it is customary to use some form of rotating or reciprocating mechanical pump sealed with oil for producing an initial or rough vacuum. In manufacturing electron discharge devices for receiving purposes, the final evacuation is ordinarily accomplished by means of a "getter" inside the device, which, when heated, will absorb gases by chemical reaction. In the case of electron discharge devices for transmitting purposes, the usual method of producing the final vacuum is to employ a Langmuir mercury vapor condensation pump of the type described in United States Patent No. 1,393,550 granted October 11, 1921 to I. Langmuir, which is operated in series with a mechanical pump. It is common practice, in both of these cases, to heat up the elements of the discharge device during the evacuation process for the purpose of driving out occluded gases from the parts of the vacuum tube. Although these methods are successful they require parts which are expensive and difficult to construct, with the result that they do not lend themselves readily to construction and operation by amateurs or to use in small laboratories. The present invention, however, by its simplicity of construction overcomes these difficulties and enables its use by amateurs, besides providing for obtaining faster evacuation and higher vacua. Another advantage of the present invention is that it is readily adaptable to large scale production of vacuum devices with the aid of automatic machines.

More specifically, the present invention comprises a vacuum pump wherein electrical forces are utilized for effecting the evacuation process. This is accomplished by producing a direct current discharge through a tube or orifice between a vessel to be exhausted and the inlet to the rough pump, the discharge consisting chiefly of a flow of electrons in one direction and a flow of gas ions and molecules in the other direction. This flow of ions continues until the vessel is exhausted. To initiate the discharge and make starting easier it is proposed to use, in a preferred embodiment, a hot cathode and a relatively low voltage supply. If desired, however, there may be used relatively cold electrodes, the arc between them being established by the momentary application of very high voltages to directly ionize the gas in the discharge path.

Although the present invention will be hereinafter described with special regard to vacuum pumps, it should be distinctly understood that it is not limited thereto since the principles thereof may be used for producing pressure as well as obtaining a vacuum.

The following is a detailed description, accompanied by drawings, wherein Figures 1, 2, 3 and 4 illustrate simple forms of the present invention. Figure 5 illustrates a further embodiment of the invention which makes use of the principles of the Langmuir pump. Figure 6 illustrates one method of starting the vacuum pump without the necessity for employing a source of very high direct current voltage.

Referring to Figure 1, there is shown a closed vessel 1 of a shape similar to an ordinary electric light bulb and having a connection from the inside thereof to a rough vacuum pump 2 of any suitable type for producing a partial vacuum within the bulb. Mounted inside the bulb is a cathode 3, which may be in the form of an ordinary electric light filament, which is arranged when heated to emit electrons. A metal electrode or anode 4, which is supplied with a positive potential from a high voltage rectifier arrangement 6 through an inductance 7, is adapted to attract the electrons emitted by the filament through a tube of insulating material 5. A suitable tubing 8 is arranged to extend from electrode 4 to vessel 9 which it is desired to exhaust. Inductance 7 is of comparatively large value and serves, once the arc has been established at the beginning of the pumping process, to increase the potential as the current in the arc tends to decrease as the vessel is evacuated, thus making it possible to obtain a higher vacuum than would otherwise be possible.

Any desired type of electrical circuit, such as 10, may be provided for lighting the filament in the bulb to produce electronic emission, and any well known source of direct current illustrated by the rectifier arrangement, such as shown in the drawings, may be used to place a positive potential on the anode 4 which is located at the end of the tubing 8.

The operation of the device is as follows:

When filament 3 is heated, a stream of electrons will flow from 3 to the positive anode 4, colliding on the way with molecules of gas in the vicinity of the anode and causing them to be ionized. This ionization will set up a discharge through the tube 5 having electrons moving from filament 3 to the anode 4 and ions moving from anode 4 to filament 3. The moving ions constitute a movement of the gas from the vicinity of anode 4 to the bulb 1 containing the filament 3. So long as the discharge takes place through a tube of small diameter such as 5 it is impossible for ions which have passed through the tube and been neutralized at the filament 3 to return again to the vicinity of anode 4. Consequently, by causing a high potential discharge between anode 4 and filament 3 there will be a movement of gas through the tube which will cause a vacuum to be produced in the vessel which is to be evacuated.

Figure 2 shows a second embodiment of my invention in which the tubing 5, of insulating material, illustrated in Figure 1 is dispensed with. In Figure 2, a hot cathode 51 is surrounded by a shielding element 53 and is placed near the opening of a metal inlet tube 52 which also acts as the anode. In operation, the cathode 51 is heated by an electrical current from source 54 over leads 55. A positive potential is applied to the metal anode element 52 by a source of potential 56 over a circuit in series with a resistance 57, thus causing the setting up of a flow of electrons from the cathode 51 to the anode 52. A portion of these electrons enter the inlet tube before striking the tube walls. The shield member 53 may have the same potential as the cathode or it may have a negative potential applied to it through a resistance 58 in the manner shown in the drawings to increase the proportion of the total number of free electrons which enter the inlet tube of metal part 52.

To start the pump, a fair degree of vacuum is first established in the system by means of a rough pump, not shown, which may be connected to opening 59. The cathode is then heated to a temperature where electrons are emitted and the potentials are applied to the other electrodes. Immediately, electrons traveling from the cathode 51 to the anode 52 begin to ionize the gases by collision, and the ions, being positively charged, are forced toward the negatively charged cathode 51 and shield 53. If the shield is more negative than the cathode most of the ions will strike the shield. This will reduce disintegration of the cathode and prolong the life of the device.

The ions produced in the inlet tube of part 52, in passing toward the cathode and shield, constitute a flow of gas out of the tube. They are replaced by molecules diffusing out of the vessel to be evacuated and consequently a very high degree of vacuum will finally be obtained.

Figure 3 shows an embodiment of my invention in which pumping is carried out by means of an electric discharge between relatively cold electrodes. In this case a source of controllable direct current potential 31 is connected to sections of metal tubing 32 and 33 which are separated by a tube of glass or other electrical insulating material 34. The connection to tubing 32 is effected through the secondary or high voltage winding of an induction coil 35. In practice the induction coil from the ignition system of a Model T Ford automobile has been successfully used. The induction coil is supplied with power from a battery, such as 36, or from any other suitable source, and serves to build up impulses of very high potential across the insulating tube 34. After a predetermined potential has been reached the gas within the insulating tube 34, which has previously been rarefied by the mechanical vacuum pump is broken down. The breaking down, or ionization, of the gas initiates an electrical discharge and permits the passage of direct current between the electrodes 32 and 33. This current is set up by the motion of electrons from electrode 33 to 32 and by the movement of gas ions from the space within the tubes to electrode 33. The gas is de-ionized by contact with electrode 33 and passes into the mechanical pump chiefly as neutral molecules. The resistance of the high voltage winding of the induction coil serves to limit the value of direct current through the discharge to a safe value. If desired, a series resistance, in addition, may be used.

Preferably, the induction coil should be so connected that the peak pulses of potential from it are in the same direction across insulating tube 34 as the D. C. voltage from the generator. The pumping action will be somewhat faster if the metal parts within the tube or vessel being evacuated are connected to the positive terminal of the generator through a current limiting resistor of proper value, such as 37.

If desired the high potential on electrode 32 may be obtained from the secondary winding of a Tesla coil or transformer. In fact the use of the Tesla coil has advantages over the use of the simple induction coil in that the resistance to direct current and the energy losses on the electrodes seem to be somewhat less. It is thought that the lower energy losses are due to the relatively short distance of travel by the ions between reversals of the radio frequency voltage from the Tesla coil, which makes the energy component of alternating current in the discharge relatively small.

It has also been found, in practice, not to be necessary to connect the Tesla coil in series with the D. C. potential supply. In some assemblages of the pumping equipment it is only necessary to subject the glass tube to the field from one terminal of the Tesla coil in order to initiate the discharge. For this purpose there has been used a coil similar to that described as Catalog No. F3685, on page 295 of Catalog F of the Central Scientific Company. Of course any other source of very high radio frequency voltage might be used in the same way.

Figure 4 shows a fourth embodiment of the present invention in which a generator 41 controllable by a field rheostat 42 is used to supply a D. C. potential to electrodes 43 and 44, and preferably, also, to the metal parts inside the tube to be exhausted. Resistances are placed in series with the leads to the electrodes to limit the flow of current to reasonable values. These resistances may be paralleled by condensers, preferably having such a capacity that the time constant of resistances and condensers matches the rate at which flashes take place through the sections of glass tube. The condensers improve the action of the pump because heavy momentary discharges are permitted by them, which exert great force in expelling the gas, without causing excessive average energy dissipation at the electrodes.

To initiate the discharge in this case, the secondary of a high voltage transformer 45, operated from ordinary alternating currents over leads 49, is used to impress a high voltage upon electrode 43. For this purpose there may be used a transformer similar to that employed for electrical ignition of oil spray in ordinary domestic oil burners. These transformers have rather high voltage regulation to limit the current through the secondary to reasonable values.

With this assemblage the pumping process is started by starting up the mechanical pump 46 which is driven by the motor 47 through gear 48. After a fair degree of vacuum is obtained, the generator 41 is started with low voltage and the transformer 45 is energized. Immediately, electrical discharges from electrode 43 to 48 will take place, and the pumping action will force gas into the inlet of pump 46. Secondary discharges will also take place from electrode 44 and from the metal parts of the tube being exhausted toward electrode 48. These secondary discharges add to the pumping action. In a short time, as the vacuum improves in the system, the discharges will become intermittent and less intense and the generator voltage may then be gradually increased to a maximum, resulting in evacuation of the tube to a very high degree. Of course, heating of the glass bulb and inner elements of the tube should be used to drive out occluded gas so that the pump can remove it.

In practice it has been found that the total amount of electrical charge which must be passed through the system is much less than the theoretical amount calculated on the assumption that each gas molecule must be ionized. Apparently, each ion collides with and drives out a large number of neutral molecules in a way similar to that in which the rapidly moving mercury molecules drive out other gases in the Langmuir mercury vapor pump, supra.

Figure 5 shows one way in which to apply the principles of the present invention for effecting an improvement in the Langmuir mercury condensation pump previously referred to. In this figure, there is shown a bulb 11 containing a filament 12 and a pool of mercury 13 through which an electric discharge may be considered to take place in the same manner as in the well known hot cathode mercury vapor rectifier tube. The presence of this electrical discharge causes ions of mercury to exist within the bulb 11, which are drawn toward the electrode 12, to which there is applied a negative potential from a direct current generator 70. The vessel to be exhausted 9 is shown connected by tubing 8 to an inlet passage 14 which, together with an orifice 39 extending from tube 11 to the inlet, connects with a condensing chamber 15. This condensing chamber is arranged to be cooled by a fluid circulating in vessel 30, the cooling fluid being conducted into the vessel 30 by means of pipe 16 and withdrawn by suction on the pipe 17. A rough vacuum pump 2, of a type similar to that shown in Figures 1 and 4 connects with the condensing chamber through a passage or inlet 18.

In the operation of the device, the heating of the mercury in the chamber 11, due to the electrical discharge in it, will build up a mercury vapor pressure while the cooling inside the vessel 30 causes it to have a much lower pressure. Consequently, a blast of mercury vapor will issue from the orifice 39. The presence of an electrical discharge will cause ions of mercury to exist within bulb 11 which, when drawn toward electrode 28 by the application of the negative potential thereto, will greatly increase the force of the blast of mercury ions in the orifice 39, which corresponds to the orifice in the Langmuir pump. The blast of ions and mercury molecules will trap and carry out molecules of gas from the inlet or conduit 14 connected to the vessel 9 to be evacuated. The ions passing through the orifice of the pump are neutralized when they come in contact with the electrode 28 and then pass as neutral mercury vapor into condensing chamber 15 where they are condensed by cooling from the cooling liquid circulated in vessel 30 around the chamber. The condensed mercury is caused to fall by gravity into a tube 19 which returns the mercury to the bulb 11. At the return end of the condensing chamber 15 there is shown the rough exhaust pump 2. By connecting the metal elements in the vessel 9 to a source of positive potential, the tendency for any mercury vapor to diffuse back into the vessel 9 will be reduced. A very low temperature may also be applied to the tube 14 in the final stages of pumping to accomplish the same purpose. Likewise, the tube 18 may be cooled to reduce the diffusion of mercury vapor into the rough pump.

Suitable circuits are shown, schematically, in a well known manner, for maintaining the electrical potentials and current discharges in the various parts of the pump.

If desired, the filament of the pumping bulb 1 in Figure 1 and the filament 12 of the mercury bulb 11 in Figure 5 may be omitted. In such case, the arc will be established between relatively cold electrodes and the apparatus is just as effective for producing the pumping action as when a heated filament is used for the negative electrode. The main reason for using filaments is to make the starting of the arc discharge easier, but this starting could also be accomplished by momentarily applying a high voltage sufficient to directly ionize the gas in the discharge path and start an arc. Another manner of starting an arc is to bring into the vicinity of the discharge path the point of a Tesla coil which will set up very high potentials around it and which will cause a break-down of the gas.

Figure 6 illustrates, in conventional form, one particular method of automatically starting the vacuum pump without the necessity for employing a very high D. C. voltage. There are, of course, numerous other ways of accomplishing the same purpose. In this figure is shown a moderately high voltage direct current source indicated as 20 which is arranged to be automatically connected at the proper time to contacts 21, 21 by the closing of a switch or the rotation of an automatic exhaust machine, not shown.

The closure of contacts 21, 21 applies direct current potential to the pump 22 which, however, may be insufficient to start an arc and cause the pump to function. In the present case, there is provided a vacuum tube 23 having a grid 24 to which there is applied a low bias, which cooperates with a transformer 25 and condenser 26 to produce oscillations. The production of oscillations supplies high voltage pulses to the pump 22 which breaks down the gas in the discharge path of the pump. At the initiation of the discharge, current flowing through resistance 27 will bias the grid 24 of tube 23 to a negative value and thus stop the oscillations. It will be noted that if, for any reason, the discharge in pump 22 ceases, tube 23 will have the bias on its grid 24 decreased so that it will again oscillate and resubject pump 22 to the very high voltage impulses.

It should be distinctly understood that the present invention is not limited to the precise arrangements and design features shown since these have merely been illustrated for the purpose of setting forth clearly the principles of the present invention. The proportions and dimensions of parts may, and undoubtedly will, be altered to obtain optimum operation with different designs.

I claim:

1. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, conducting electrodes at each end of the tube, a source of direct current connected to the electrodes and means to produce high momentary potentials within the tubing for initiating a gaseous discharge therein with consequent motion of gas out of the vessel to be evacuated.

2. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, conducting electrodes at each end of the tube, a source of direct current, and connections from said source to said electrodes, a winding in one of said connections, a second winding coupled to said first winding, and circuit means for producing in said second winding interrupted high potentials whereby there is initiated a gaseous discharge within said tube with consequent motion of gas out of the vessel to be evacuated.

3. Apparatus as defined in claim 2, characterized in this, that said windings are so connected that peak pulses of potential are in the same direction across said insulating tube as the voltage from said source of direct current.

4. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, a metallic electrode in contact with said tube, a source of direct current connected to said electrode, and circuit means connected to said metallic electrode for producing periodically interrupted high potentials whereby there is initiated a gaseous discharge within said tube with consequent motion of gas out of the vessel to be evacuated.

5. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, conducting electrodes at each end of the tube, a source of direct current, and connections from said source to said electrodes, an induction coil in one of said connections, and circuit means for producing in said induction coil interrupted high potentials whereby there is initiated a gaseous discharge within said tube with consequent motion of gas out of the vessel to be evacuated.

6. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, conducting electrodes at each end of the tube, a source of direct current, connections from opposite terminals of said source to said electrodes respectively, a resistance shunted by a condenser in one of said connections, and means for producing a gaseous discharge across said electrodes with consequent motion of gas out of the vessel to be evacuated.

7. Apparatus in accordance with claim 6, characterized in this that said insulating tubing comprises glass, and the values of said resistance and condenser are such that the time constant thereof matches the rate at which discharges take place through said tubing.

8. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, said vessel having metallic parts therein, conducting electrodes at each end of the tube, a source of direct current connected to the electrodes, the negative terminal of said source being connected to the electrode farthest away from said vessel and the positive terminal being connected to the other electrode and to the metallic parts of said vessel, and means to produce high momentary potentials within the tubing for initiating a gaseous discharge therein with consequent motion of gas out of the vessel to be evacuated.

9. Apparatus for producing a vacuum comprising, in combination, a vessel to be evacuated, a rough vacuum pump, a plurality of sections of insulating tubing arranged in series relation extending from said vessel to said pump, there being a metallic electrode at the junction of every two sections of tubing, and a metallic electrode at the end of the last section farthest removed from said vessel to be evacuated, a source of direct current, a connection from one terminal of said source to said last electrode, and a connection from the other terminal of said source to said other electrodes, and means for producing intermittent gaseous discharges between said electrode farthest removed from said vessel and one or more of said other electrodes with consequent motion of gas out of the vessel to be evacuated.

10. Apparatus for producing a vacuum comprising, in combination, a tubing of insulating material forming part of a connection through which a vessel is to be evacuated, conducting electrodes at each end of the tube, a source of direct current having a negative terminal connected to the electrode farthest removed from the vessel, and a positive terminal connected to the other electrode, and means to produce high momentary potentials within the tubing for initiating a gaseous discharge therein with consequent motion of gas out of the vessel to be evacuated.

11. Apparatus for producing a vacuum comprising, in combination, three electrodes separated from one another by tubing material forming part of a connection through which a vessel is to be evacuated, a source of direct current having one of its terminals connected to that one of the electrodes which is farthest removed from the vessel to be evacuated and the other of its terminals connected to the other electrodes, and means in circuit with one of the connections from said source to one of the electrodes for producing therein, periodically, high frequency potentials whereby there are initiated gaseous discharges within said tubing with consequent motion of gas out of the vessel to be evacuated.

12. Apparatus as defined in claim 11, characterized in this, that said means for producing the high frequency potentials is in circuit with the connection from the center one of the electrodes, and said means comprises a source of alternating current.

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