No. 820,364. PATENTED MAY 8, 1906.

D. McF. MOORE.

VACUUM TUBE REGULATOR.

APPLICATION FILED AUG. 21, 1905.

2 SHEETS—SHEET 1.

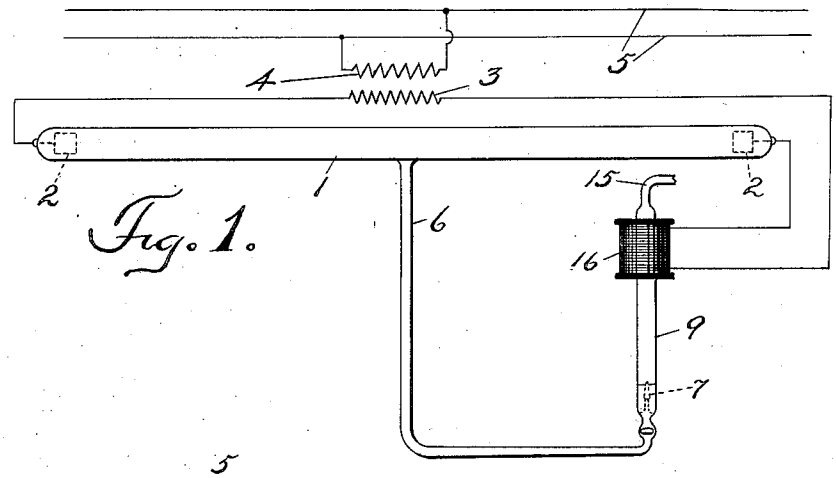


Fig. 1.

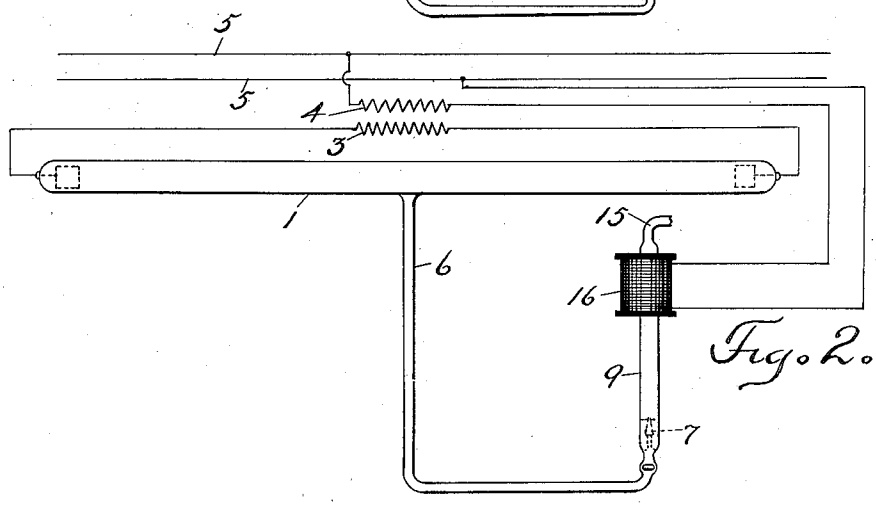


Fig. 2.

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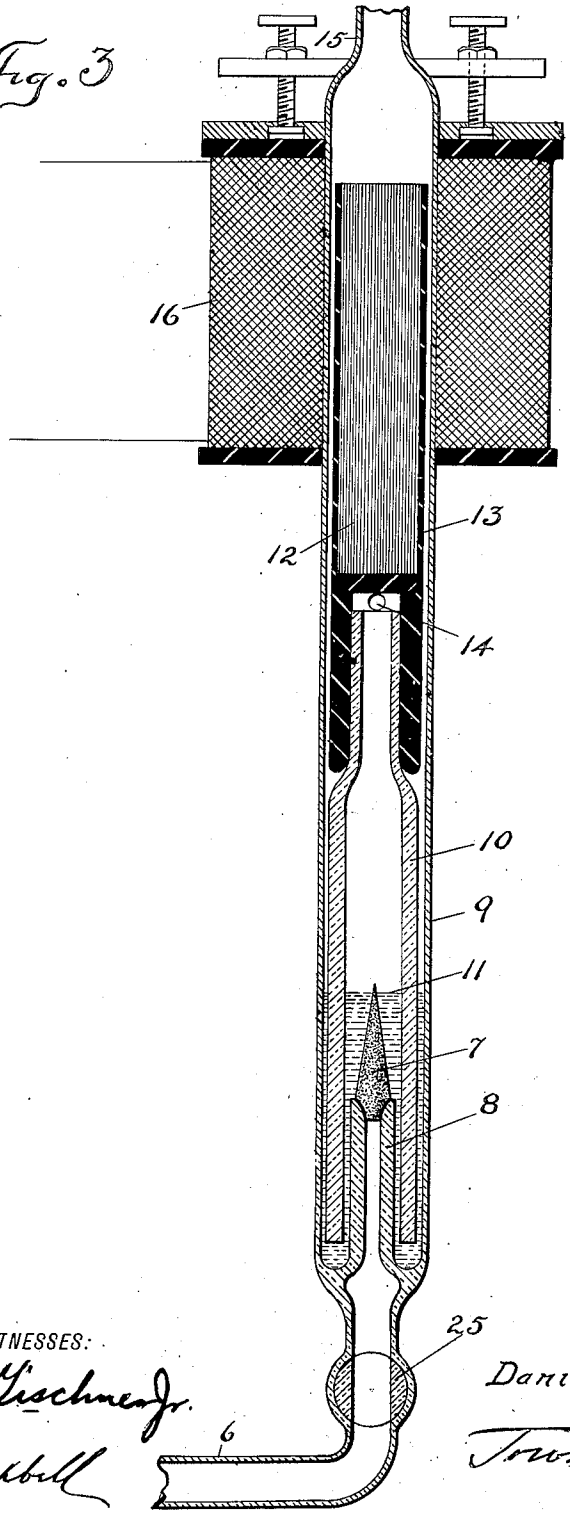
2 SHEETS—SHEET 2.

Fig. 3

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# UNITED STATES PATENT OFFICE.

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## VACUUM-TUBE REGULATOR.

No. 820,364. Specification of Letters Patent. Patented May 8, 1906.

Application filed August 21, 1905. Serial No. 275,003.

*To all whom it may concern:*

Be it known that I, DANIEL McFARLAN MOORE, a citizen of the United States, and a resident of Newark, in the county of Essex and State of New Jersey, (whose post-office address is 52 Lawrence street,) have invented certain new and useful Improvements in Vacuum-Tube Regulators, of which the following is a specification.

The present invention relates to vacuum-tube or vapor electric lamps, vacuum or vapor rectifiers, X-ray tubes, vacuum oscillographs, wireless-telegraph receivers, and other devices which generally may be classified under the head of "vacuum-tubes" and which are provided with suitable electric terminals whereby electric energy may be applied to the gaseous contents of the tube for any purpose.

The object of the present invention is to remove the difficulty hitherto met with in the operation of this general class of apparatus from deterioration or variation of the vacuum or gaseous or vapor tension or in the case of lamps from the gas becoming spent or losing its light-giving and conducting function as the vacuum gets higher.

My present invention consists, substantially, in combining the tube with a body or source of gas of greater density than that in the tube and connected with the tube by a suitable pipe or passage and in employing suitable means whereby the gas may be fed from such source automatically in response to changes in the gaseous condition within the tube and in determinate or regulated amount such as will maintain a practically normal gaseous condition within the tube.

My invention is especially useful for vacuum-tube lamps, since it permits them to be run for an indefinite time and with any desired degree of luminosity and with any desired gas.

By my invention the necessity of reëxhausting the tube and the difficulties incident to the use of a solid material inclosed in the tube and used as a generator or regenerator of gas or vapor may be entirely removed or obviated.

The regulated flow of gas is preferably secured by devices operating after the manner of a valve and controlled in their action by some means automatically responsive to changes of the gaseous condition or tension within the tube. Thus, for instance, in the case of vacuum-tube lamps in which air or similar gas is used the valve may be operated or controlled by an electromagnet connected to the electric circuit of the lamp in such manner as to respond to the decrease of electric resistance within the lamp when through use the vacuum rises or the gas loses its light-giving power.

The invention consists also in the special combinations of devices for automatically regulating the flow of the gas and in other features of construction more particularly hereinafter described and then pointed out in the claims.

In the accompanying drawings, Figure 1 is a general side elevation of a form of vacuum-tube lamp combined with means for practicing the invention. Fig. 2 shows a modification in the manner of connnecting up the regulating-magnet when a magnet is employed. Fig. 3 is a vertical section through the electromagnetic gas-regulator which it is preferred to employ.

The invention will be herein described as carried out in connection with an electric tube-lamp in which air or other gas is employed.

1 is the tube, of glass, and 2 the internal electrodes joined to conductors sealed in the tube and furnished with electric energy supplied from any source—as, for instance, the secondary 3 of a transformer the primary 4 of which is connected to the mains 5.

At 6 is shown a pipe sealed to the tube 1 at any point. Said pipe is a gas-feed pipe, through which the air or gas is fed into the tube to compensate for any increase of the vacuum through a suitable valve and at a slow rate automatically determined by changes in the pressure of the air or gas in the tube.

In practice it will be found desirable to permit the air or gas from the source to perco-

late through a mass of porous material, since by this means any sudden influx of air or gas and any consequent sudden fluctuation of the gaseous tension within the tube can be avoided.

One of the forms of valve that may be used in carrying out my invention is as follows: Referring to Fig. 3, 7 indicates a mass of any porous material—as, for instance, carbon—which is sealed, like a stopper, in the end of a tube 8, joined or leading to pipe 6 and the lamp. The exposed end of the plug or mass 7 is located in a chamber 9, wherein is maintained a pressure of air or other gas suitable for use in the lamp. Tubes 8 and 9 are preferably concentric and are arranged, as shown, to form an annular chamber which receives the lower end of a plunger or liquid-displacer 10, and in the chamber 9 is a body of liquid 11, consisting of mercury or other liquid, which surrounds the mass of porous material 7, leaving the upper terminal of the same exposed or adapted to be exposed by a slight change of level of the liquid 11, brought about in any way—as, for instance, by the operation of the displacer 10, which for that purpose can be suspended from the core 12 of an electromagnet. By moving the displacer the tip of the mass 7 may be more or less exposed or by a suitable adjustment may be alternately exposed and sunk beneath the level of the liquid, so as to vary the extent of the porous surfaces through which gas under pressure may leak into and through the mass 7. As indicated in Fig. 6, the mass might have its tip constantly exposed, the minute leakage being determined by the small size of the tip and the length of the mass. It is preferred to taper the point of the tip for the purpose of preventing a marked change in the extent of exposure for a small change in the level of the liquid. As will be seen, the mass 7 interposes resistance to the flow of gas, regulated by the height of the liquid in which it is immersed. The plunger 10 is preferably of glass, like chamber or tube 9, to permit the plug 7 and the position of its tip in the liquid to be observed. The plunger or displacer may be attached to the core 12 by means of indurated fiber tube 13, which carries core 12, of iron wires. The space within the cylindrical displacer 10 is in communication with any source or body of gas under pressure—as, for instance, the atmosphere—through a hole 14, communicating with the spaces in the tube 9, which latter receive the air or other gas through pipe 15. An adjustment of the vertical position of the displacer to determine the extent to which the tip of the mass 7 shall be normally exposed above the level of the liquid may be secured by adjusting the position of the coil 16 of the electromagnet vertically on the tube 9. Mercury is preferred, because it forms an effective air seal and does not clog the pores of the porous mass 7. Inasmuch as the plunger works in the same body of liquid in which the tip of the valve proper is located and is exposed to the same pressure of incoming gas, it is obvious that any changes in such pressure will not affect the height of the liquid so as to disturb the adjustment of the valve, and the same will therefore work in a uniform manner in response to the action of the magnet and irrespective of variations in the pressure of the body of gas constituting the source of supply.

The coils 16 of the electromagnet may be connected in a variety of ways so as to feel the effect of a change of resistance within the lamp. As shown in Fig. 1, they may be in series with the lamp and secondary core; but they might be in series with the primary core when the lamp is operated on a constant-potential system. They might, as well understood in the art, be connected in other ways to the circuit of the translating device so as to be responsive to change in the resistance or change in the vapor or gas tension therein. As is well known, there is a critical tension or degree of vacuum in the tube, at which the resistance to the passage of electrical energy through the gas from one electrode to the other of the tube is at its lowest. If the vacuum increased beyond this critical point, the resistance increases and the current falls. It is preferable to operate the tube below the degree of vapor or gas tension at which the resistance and current change from a decreasing value of resistance and increasing value of current to an increasing value of resistance and decreasing value of current; but for economy the degree of vacuum should be maintained as near as possible to the point where the resistance is least, though sufficiently below such point to avoid the possibility of changes of tension extending over to the degree where the resistance will increase with an increase of the vacuum. In the operation of the apparatus when the vacuum in the lamp becomes slightly higher through continued action of the electric energy upon the gaseous contents the resistance decreases and slightly more current flows through the magnet, which thereupon causes the height of the liquid-level to fall by lifting the displacer 10. This permits gas to flow through the tip of the plug or pencil 7 into the lamp until the normal gaseous condition therein is restored and the tube is made to conduct less current, so that the magnet will let the displacer 10 fall again.

By adjustment of the magnet any desired degree of vacuum in the tube or any desired degree of intensity of light can be maintained within narrow limits.

It will be seen that the liquid 11 by buoy-

ing the plunger 10 acts to counterbalance the weight of the parts operated by the magnet. The constancy of condition in the tube can obviously be maintained by an adjustment of the parts such that each excursion of the plunger to and fro will result in an uncovering and complete covering of the tip of the plug, or the tip may be at all times exposed and the action be by an increase and decrease of the amount of tip that is exposed. By placing a stop-cock 25 in the connection between the valve and the lamp it is practical to produce a portable apparatus—that is, after the tube is placed in operative condition at the factory stop-cock 25 is turned off, the tube as a whole inverted, or by other means the mercury 11 is removed. This permits the gas-pressure to become high up to the stop-cock 25. When the lamp is again set up for use after shipment, the correct amount of mercury is first poured into the glass tube 9, and then the stop-cock 25 is very gradually opened—that is, by slow stages—so that the tube gradually uses up the air which was entrapped between the bottom of the porous plug 7 and the stop-cock 25. After it is all used up, which can be determined in a number of ways, but principally by the appearance of the light, the stop-cock 25 will be turned on full, and the feeding of the gas to the tube will then become automatic, as before described.

Fig. 2 shows simply a modification wherein the magnet is connected to the primary instead of the secondary of the transformer.

My invention is applicable not only to lamps having internal electrodes, but also to those having external electrodes wherein the energy is transmitted by electrostatic induction to the contents of the lamp.

For the porous plug I find a rather dense arc-light carbon to be suitable. The denser the carbon the less the length of plug necessary. The utility of the arc-light carbon is due largely to the fact that it holds its particles in a constant fixed relation, so as to maintain a constant resistance to the flow of the gas. Moreover, it is generally of uniform porosity and free from the presence of large spaces through which the gas might pass in unduly large amounts.

By the insulation of the displacer from the core the high-tension electricity of the lamp is prevented from working back to the coils of the magnet.

It is obvious that my invention is applicable to tubes supplied either with alternating or direct currents.

The pressure or density of the body of gas which is fed into the tube may be anything higher than the vapor or gas tension or density within the tube itself. In practice and as well understood in the art the tension or density of the gas within the tube is much less than that of the atmosphere and would be ordinarily a small fraction of a millimeter, varying, however, to some extent with the length and diameter of the tube, the kind of gas employed, and the use to which the vacuum-tube is put.

In the present case the special construction of gas check or valve for regulating the flow of gas is not claimed *per se*, but only in combination with the vacuum-tube; nor do I claim herein the method of keeping the luminosity constant by feeding the gas from a body of gas under pressure into the tube in determinate automatically-regulated amount or rate such as will keep the gaseous contents constant in tension or nature, nor the method of maintaining the vacuum at the desired tension to produce the required luminosity by automatically regulating the flow through changes in the current-supply, inasmuch as the construction of gas valve or check itself and the general methods of maintaining the vacuum form the subject of another application for patent filed by me as a division of the present application on the 7th day of February, 1906, Serial No. 299,883. I have also claimed in said divisional application the combination, with the vacuum-tube lamp, of a transformer and a magnet connected with the primary circuit for controlling the flow of gas to the lamp.

What I claim is—

1. The combination of a vacuum-tube connected to a body of gas of greater density than that in the tube, and means responsive to changes in the gaseous condition within the tube for automatically feeding gas from such body of gas into the tube in determinate or regulated amounts proper for maintaining the gaseous contents of the tube in the standard or normal condition.

2. The combination of a vacuum-tube connected with a body of gas of greater density than that in the tube, a mass of porous material interposed in the passage between the tube and such body of gas, and means for varying the extent of surface of porous material exposed to the pressure of said body of gas in order to regulate the flow of gas to the tube.

3. The combination of a vacuum-tube, a source of gas, a valve between the source and tube and an actuating-magnet for said valve responsive to changes in the gaseous condition within the tube.

4. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, and a body of porous material interposed in a passage between the source and the tube, as and for the purpose described.

5. The combination of a vacuum-tube, a source of gas of greater density than that in

the tube, and a body of carbon interposed in a passage between the source and the tube, as and for the purpose described.

6. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a body of porous material interposing an obstacle to the free flow of the gas, and means for varying the amount of material in action, as and for the purpose described.

7. The combination with a vacuum-tube of a source of gas of greater density than that in the tube, a mass of porous material interposing an obstacle to the free flow of the gas, a body of liquid, and means for varying the extent of the porous material exposed above the liquid to vary the flow of gas.

8. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a mass of porous material having a tapered terminal and interposing an obstacle to the free flow of gas to the tube, a body of liquid surrounding said terminal, and means for varying the exposure of the terminal above the liquid.

9. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a mass of porous material restricting the free flow of gas to the tube and having a tapered terminal, a body of liquid surrounding said terminal, and means for varying the height of the liquid.

10. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a gas-valve between the source and the tube, and means responsive to variations in the gaseous condition within the tube for actuating the valve.

11. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a gas-valve between the source and the tube, and means responsive to changes of electric resistance between the two electrodes for actuating the valve.

12. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a valve for governing the flow of such gas to the tube, and an electromagnet responsive to changes of the electric resistance of the tube for actuating the valve.

13. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a mass of porous material interposing resistance to the free flow of gas, and means responsive to changes of gaseous condition in the tube for varying the resistance.

14. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a mass of porous material interposing resistance to the free flow of gas, and means responsive to variations in the electric resistance of the tube for determining the effective resistance of the mass of porous material.

15. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a mass of porous material interposing resistance to the free flow of gas, an electromagnet and means actuated thereby for varying the effective resistance of the mass of porous material.

16. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a mass of porous material surrounded by a liquid and adapted to restrict the free flow of gas, an electromagnet and means actuated thereby for varying the exposure of the porous material above the level of the liquid.

17. The combination of a vacuum-tube, a source of gas of greater density than that in the tube, a body of porous material, restricting the free flow of gas and having a pointed terminal, and a body of liquid in which the terminal is immersed.

18. The combination of a vacuum-tube, a mass of porous material interposed in a gas connection of said tube, a body of liquid surrounding the terminal of said mass, an electromagnet, and means for varying the exposure of the terminal above the liquid.

19. The combination of a vacuum-tube, a mass of porous material interposed in a gas connection of said tube, a body of liquid in which the mass of porous material is immersed, and means for displacing the liquid to vary the exposure of the porous material.

20. The combination of a vacuum-tube, electric terminals therefor, an adjustable gas-valve in a passage communicating with the tube and means responsive to variations in resistance between the terminals of the tube for actuating the valve.

21. The combination with a vacuum-tube, a gas-valve comprising porous material and liquid, a displacer in the body of liquid, an actuating-electromagnet and means for insulating the displacer and magnet.

22. The combination with a vacuum-tube and a gas-valve provided with a body of mercury by whose rise and fall the flow of gas is determined, a liquid-displacer of insulating material and an actuating-electromagnet.

23. A vacuum-tube lamp containing air in a rarefied condition as a luminous agent combined with means responsive to variations in the degree of rarefaction for admitting air to the tube in regulated amounts to maintain a normal luminosity.

24. A vacuum-tube lamp containing a gas in a rarefied condition acting as the luminous agent combined with means responsive to variations in the degree of rarefaction for admitting gas to the tube in regulated amounts to maintain a normal luminosity.

25. A vacuum-tube containing a gas in a rarefied condition combined with means re-

sponsive to variations in the degree of rarefaction for admitting gas to the tube in regulated amounts to maintain the desired degree of vacuum.

26. The combination with a vacuum-tube of a source of gas of greater density than that in the tube, a mass of porous material between the tube and source, a body of mercury and means for varying the extent of porous material exposed above the mercury to vary the flow of gas.

27. The combination with a vacuum-tube lamp, of a piece of porous arc-light carbon interposed in a passage between the tube and a body of gas under pressure, a body of mercury in contact with the carbon, and means for adjusting or regulating the extent of contact.

28. The combination of a vacuum-tube and a piece of porous arc-light carbon interposed in a passage leading to the tube and acting as a resistance to the free flow of a gas.

29. The combination of a vacuum-tube lamp and a plug or pencil of porous carbon through whose pores gas can leak to the tube.

30. The combination of a vacuum-tube lamp, a porous plug, mercury in contact with said plug, and means for changing the level of the mercury with relation to the plug.

31. The combination of a vacuum-tube lamp, a porous plug, mercury in contact with said plug and means for automatically changing the level of the surface of the mercury with relation to the plug when the condition of the vacuum in the tube changes.

32. The combination of a vacuum-tube lamp, a porous plug, immersed in mercury and an electromagnet varying in strength with variations in the electrical condition of the tube for changing the level of the surface of the mercury.

33. The combination of a vacuum-tube lamp, a porous plug, a body of mercury in contact with said plug and a displacer to raise or lower the surface of the mercury.

34. The combination of a vacuum-tube lamp, a body of mercury whose changes of level regulate the flow of gas to the lamp, and a displacer of mercury for adjusting its level.

35. The combination of a vacuum-tube lamp, a body of mercury by whose changes of level the flow of gas to the tube may be changed, and means for regulating the level of the mercury.

36. The combination of a vacuum-tube lamp, and means for regulating the vacuum comprising a transformer, a magnet connected to the secondary circuit of said transformer and a valve actuated by the magnet and controlling the flow of gas to the tube.

37. The combination of a vacuum-tube, a chamber containing mercury and communicating with a source of gas of greater density than that in the tube, a porous plug immersed in the mercury of said chamber and through which the air or gas under pressure may pass from said chamber to the tube, and a liquid-displacer working in the mercury to allow the whole surface of the mercury to be exposed to the gas-pressure, as and for the purpose described.

38. The combination of a vacuum-tube, a porous plug in a passage leading to the tube, a body of mercury in which the plug is immersed, a displacer of the mercury, and an actuating-magnet adjustable for the purpose of adjusting the level of the liquid, and consequently the flow of gas.

39. The combination of a vacuum-tube, a valve operating by changes of liquid-level and controlling the admission of gas to the tube, a liquid-displacer for changing the level of the liquid and an actuating-magnet therefor adjustable in position for the purpose of adjusting the position of the displacer and thereby adjusting the degree of vacuum maintained in the tube.

40. The combination of a vacuum-tube lamp, a valve operating by changes of a liquid-level and connected to the lamp, a liquid-displacer for changing the level of the liquid, and an actuating-magnet therefor adjusted in position for the purpose of controlling the intensity of the light.

41. The combination of a vacuum-tube and means automatically responsive to changes in the vacuum for admitting gas to the tube from a body of gas of greater density than that of the gas within the tube.

42. The combination of a vacuum-tube lamp and means automatically responsive to changes in the vacuum for admitting gas to the lamp from a body of gas of greater density than the gas within the lamp so as to keep the luminosity practically constant.

43. The combination of a vacuum-tube and a valve comprising a containing-chamber, porous material in a passage leading from the chamber to the tube and adapted to allow gas to percolate from the chamber, a suitable liquid in said chamber and a displacer for varying the level of the liquid.

44. The combination of a vacuum-tube, and automatic magnetic means for feeding gas to the tube.

45. The combination of a vacuum-tube lamp and automatic magnetic means for feeding gas to the lamp to keep the luminosity constant.

46. The combination of a vacuum-tube, devices for feeding gas to the tube and electromagnetic means acting in response to changes in the vacuum for bringing the feeding devices into action in order to admit gas to the tube.

47. The combination of a vacuum-tube, a valve, and means responsive to changes in

the electrical resistance of the gas in the tube for feeding gas into the tube through the valve.

48. The combination of a vacuum-tube lamp, a valve, and means responsive to changes in the electrical resistance of the gas in the lamp for feeding gas into the lamp through the valve.

49. The combination of a vacuum-tube and means for feeding gas to the tube automatically when the electrical resistance of the gas in said tube decreases.

50. The combination of a vacuum-tube lamp and means for feeding gas to the lamp automatically in response to decrease of the electrical resistance of the gas in the lamp.

Signed at New York, in the county of New York and State of New York, this 16th day of August, A. D. 1905.

DANIEL McFARLAN MOORE.

Witnesses:
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JOSEPH CAMPBELL.