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F. M. PENNING
ELECTRIC DEVICE AND METHOD FOR HEATING MATERIALS
Filed Feb. 26, 1941

Serial No. 380,728
2 Sheets-Sheet 1

Fig. 1.

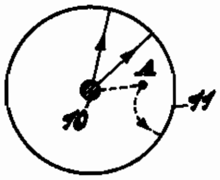
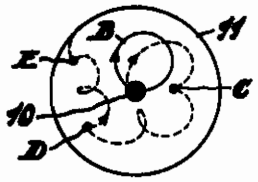


Fig. 2.



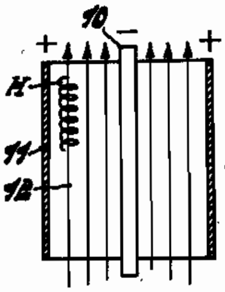


Fig. 3.

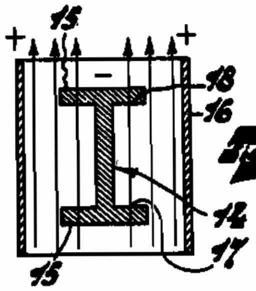
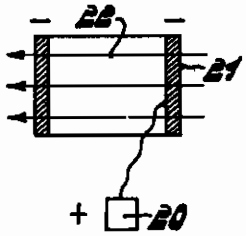


Fig. 4.



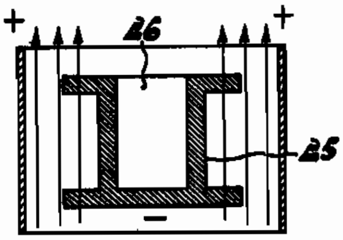


Fig. 5.

Fig. 6.

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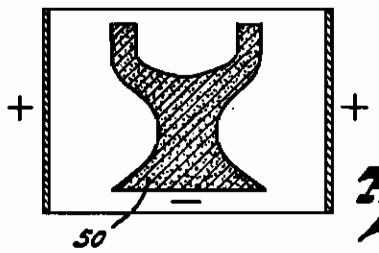

Fig. 8

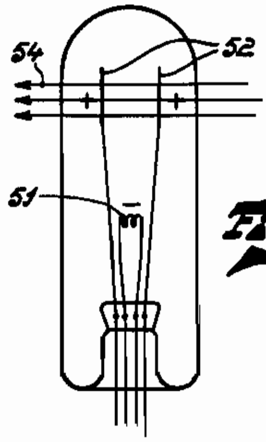

Fig. 9

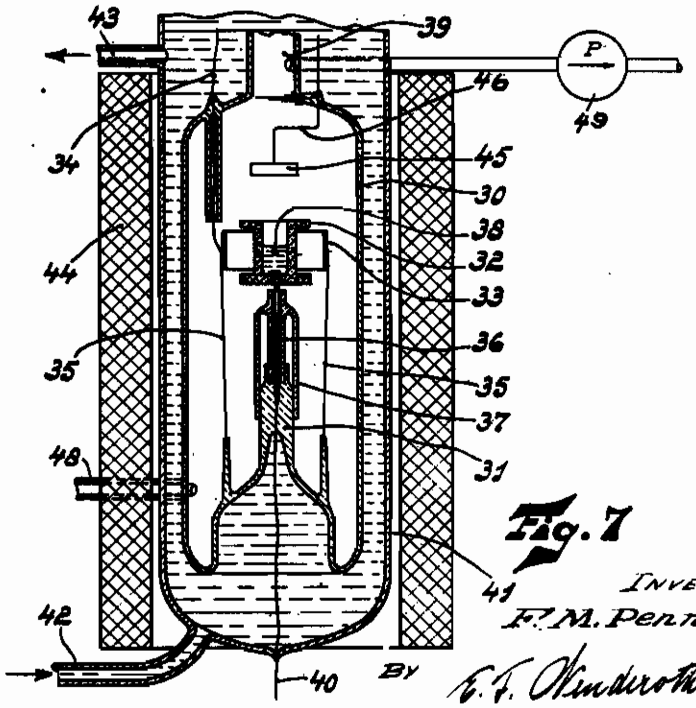

Fig. 7

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ALIEN PROPERTY CUSTODIAN

ELECTRIC DEVICE AND METHOD FOR HEATING MATERIALS

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Electric furnaces are known in which materials are heated by high-frequency currents in a gaseous atmosphere of low pressure to very high temperatures. The equipment necessary for this purpose is rather expensive, we have only to think of the required generator. As a consequence thereof there exists the need of a less expensive electric furnace with which such heating operations can be carried into effect.

According to the invention, for heating materials above 750° C. the source of heat is furnished by a glow-discharge which takes place in a magnetic field which greatly lengthens the electron paths. This method permits us to obtain temperatures of the order of 2000° C. with an equipment which may be referred to as little expensive in comparison with the above-mentioned furnaces. Thus the magnetic field may be provided either by an electromagnet or by a permanent magnet while the heating operation may take place in a closed glass space. The gas in this space may have a low pressure.

It is already known to effect heating operations by means of a glow discharge. For example, it has previously been proposed to de-gas electrodes by means of a glow-discharge. When we desire to effect this heating at a higher temperature we encounter the drawback that the glow-discharges too readily pass into arc discharges, due to which the heating is concentrated at a single point and, besides, the energy greatly decreases since the arc discharge has a much lower operating voltage than a glow-discharge.

If now the paths along which the electrons travel from the cathode to the anode are greatly lengthened by a magnetic field, this will be found to have a stabilizing effect on the glow-discharge and, besides, to create the possibility of heating the cathode for a longer time to high temperatures. A further advantage is that with the same supply of energy as otherwise would be required for the glow-discharge lower gas-pressures and lower voltages may be utilised. More particularly the latter fact augments the possibility of application of the invention. It is obvious that the strength of the magnetic field must be efficiently chosen in connection with the voltage existing between the electrodes and with the pressure of the gas. It is, of course, a requirement that the radius of the arc according to which the electrons are deflected under the influence of the magnetic field should be of the same order of magnitude as or smaller than the length of the free path between the gas molecules.

The above-mentioned method may be carried out in different ways. Thus, the heating device may be constructed as a furnace and the body to be heated may be given the shape of a vessel in the hollow interior of which are provided the materials to be heated, melted or vaporised. It is also possible to utilise the body to be heated as a radiator of light and to use the device as a lamp. Finally the method may also be utilised for heating electrodes for a long time to a high temperature in order to remove occluded gases to a satisfactory extent.

In the above-mentioned cases the body to be heated or the furnace may be arranged, if desired, in a space of reduced gas-pressure. The arrangement should preferably be such that the gas-pressure in this space may be varied and may be adjusted during the glow-discharge to the most favourable value. This affords the further advantage that the glow-discharge can be more easily ignited at a higher pressure whilst, once ignited, it may be continued at a low pressure. Besides, during the glow-discharge all the gas may be pumped off, during which operation the discharge is extinguished, it is true, but the heated object still remains for sometime in vacuo at a high temperature. For the purpose of regulating the pressure it is often efficacious to cause the gas continually to flow-in on the one side of the tube and to pump on the other side. Besides, in this way a continual renewal of gas takes place, which may be desired in those cases wherein during the heating many contaminating gases are set free.

According to one form of realisation of the method according to the invention the glow-discharge is caused to take place in helium of low pressure for as compared with most other gases the cathode volatilisation is in helium very slight.

The invention will be explained more fully with reference to the accompanying drawings in which

Fig. 1 represents diagrammatically a concentrically arranged cathode and anode and the course of the electron paths between them.

Fig. 2 diagrammatically represents the cathode and anode according to Fig. 1 and the electron paths as produced under the influence of a magnetic field perpendicular to the plane of the drawing.

Fig. 3 is a lateral elevation of Fig. 2.

Fig. 4 shows the arrangement of a modified form of cathode with a cylindrical anode, part of the operative surface of the cathode being cut by the lines of force of the magnetic field.

Fig. 5 represents a cylindrical cathode, an anode arranged outside thereof and a magnetic field which is perpendicular to the axis of the cathode.

Fig. 6 shows a cathode formed as a vessel and surrounded by a cylindrical anode.

Fig. 7 represents a furnace according to the invention.

Fig. 8 is a different form of construction of the cathode in the furnace according to Fig. 7.

Fig. 9 represents a discharge tube having arranged in it an auxiliary electrode by which the removal of occluded gases from the anode is rendered possible.

Fig. 1 diagrammatically represents a cylindrical cathode **10** and a cylindrical anode **11** which are coaxially arranged in a gaseous atmosphere of low pressure. If a voltage is applied to these electrodes the electrons proceeding from the cathode travel in vacuo according to the radially extending lines. In the presence of gas they collide with a gas atoms; with a low-gas pressure the path of an electron may assume, for example, due to a collision at A, the shape indicated by a dotted line. If the anode voltage is high enough ionisation may occur upon these collisions; the positive ions formed are drawn to the cathodes and may set free therefrom not only the electrons required for their neutralisation but also further electrons. Assuming that an electron starting from the cathode forms on an average n ions on its way to the anode, an independent discharge will occur when these n ions set free together one additional electron from the cathode. During this discharge there occurs in the cathode a luminous phenomenon from which this discharge derives the name of glow-discharge. This luminous phenomenon is due to the lighting-up of the atoms hit by electrons. Owing to the frequent collisions of ions against the cathode the latter is heated more and more. When the energy supplied to the discharge increases, the possibility of the discharge passing from a glow-discharge into an arc discharge steadily increases. During the arc discharge the heating will be concentrated rather at a single point whilst the energy greatly decreases since the arc discharge has a much lower operating voltage than the glow discharge. The cathode is therefore heated to a much lower temperature.

In Fig. 2 the course of the electron path in vacuo is indicated by a curve B with the same cathode **10** and anode **11** as are shown in Fig. 1. The difference is, however, that this cathode and this anode are arranged in a magnetic field whose lines of force are perpendicular to the plane of the drawing (the crosslets indicate where the lines of force cut the plane of the drawing). Due to this magnetic field the electrons undergo a strong deflection from the rectilinear path which they would attempt to follow under ordinary conditions. They are deflected according to a curve B whose radius of curvature depends at any point on the voltage between the electrodes and on the strength of the magnetic field. If the space is filled with gas of a very low pressure, these factors may advantageously be so chosen that this radius of curvature becomes of the same order of magnitude or small with respect to the length of the free paths between the gas atoms. Owing to this, the electron, for example after having left the cathode, will describe through the magnetic field a path towards the anode as is diagrammatically shown in Fig. 2 by a dotted line. It may be seen how the electron successively collides in its path with gas atoms C, D and E. Since in these collisions the electron energy it can no longer reach the cathode whilst, on the other hand, it is prevented by the magnetic field from attaining the anode. In this way it may take a very long period of time before the electron has lost sufficient energy to reach the anode. This path is considerably longer than that in Fig. 1 so that also considerably more collisions with the gas atoms take place and consequently with lower voltages and a lower gas-pressure the same heating of the cathode may be attained and, besides, it is achieved that the glow discharge is stable and has little tendency to pass into the arc discharge.

Fig. 3 shows in lateral elevation the arrangement of Fig. 2. Moreover, the magnetic lines of force are indicated by arrowed lines **12** which extend parallel to the cathode. When an electron acquires a speed component parallel to the magnetic field this component is not influenced by the magnetic field. So long as the electron makes no collisions it consequently moves in a spiral path around a magnetic line of force and thus it may leave the discharge space. In order to prevent this Fig. 4 shows a shape of cathode **14** which is provided with flanges **15** and is arranged coaxially with respect to an anode **16**. The magnetic lines of force are parallel to the axis of the cathode and cut the operative surface at the point **17** where they enter into the discharge space and at the point **18** where they leave said space. Owing to the latter fact the electrons which should have the tendency indicated in Fig. 3 will when approaching the cathode wall, travel again in the opposite direction while moving around the lines of the magnetic field and travel in a zig-zag line between the flanges of the cathode to the anode. It is clear that the paths of these electrons are considerably lengthened and that consequently the possibility of collisions with atoms is appreciably increased.

Fig. 5 represents a further form of construction wherein an anode **20** is arranged outside a cylindrical cathode **21**. The lines of force **22** of the magnetic field are perpendicular to the axis of the cathode. If desired, the cathode may also be given the shape of two plates arranged opposite one another, the magnetic field being perpendicular to these plates.

Fig. 6 represents a cathode **25** which essentially is formed with flanges as is the cathode **14** of Fig. 4 but, in addition, it has a central cavity **26** in which may be introduced a material which is heated by heat delivered by the cathode. Fig. 7 represents a heating furnace equipped with a cathode which offers these possibilities. The discharge tube consists of a wall **30** of pyrex having sealed into it a stem **31** on which is mounted a cathode **32** provided with a cavity. The cathode is surrounded by an annular anode **33** which is led out of the tube by a conductor **34** and is maintained in its position by supporting wires **35**. The pinch **31** and the conducting wire **36** of the cathode are further surrounded by a tube **37** of quartz which safeguards the pinch against arcing. The material to be heated **38** is introduced through an aperture **39** into the cathode **32** whereupon the interior space of the tube **30** is filled with gas of low pressure. The tube **30** is placed in a cooling vessel **41** provided with a supply conduit **42** and a discharge conduit **43** and is further surrounded by a coil **44**. In connection with the gas-pressure prevailing in the tube and with the voltage to be applied between leading-in wires **34** and **40** the magnetic field set up by the said coil may be so chosen that the paths of the electrons are considerably lengthened. Due to the glow-discharge produced the cathode is very strongly heated and temperatures above 1000° C., if desired even temperatures of about 2000° C, may be attained, this heat being delivered to the material 38 which liquefies or vaporizes. In order to ensure that the cathode can sustain these temperatures it is made, for example, of graphite. It is efficacious to utilize in this heating a filling of helium, preferably at a pressure of 5 mms at the most since in helium volatilisation of the operative cathode wall occurs to a less extent. The arrangement of Fig. 7 is utilised, for example, for applying the material vaporised in the cathode 32 by vaporisation to a body 45 which is also mounted in the tube by means of a supporting wire 46. It is obvious that the tube must be of other construction if we intend to effect fusions of metals within the cathode 32 for in such cases it is necessary that the molten material can be easily removed from the cathode 32 or that the whole of this cathode is detachably mounted on the supporting rod 36 and may be removed through the aperture 39 from the tube 30. It is also possible to modify the pressure of the gas within the tube 30. For example, at the outset a higher pressure may be taken in order to effectuate a more easy ignition of the glow-discharge. When this discharge has once been ignited the pressure may be reduced. It is also possible to provide the tube 30 in addition to the outlet aperture 39, with an inlet aperture 48 (indicated by dotted lines), owing to which renewal of the gas may be realised by the continual supply and discharge of gas.

Fig. 8 represents a cathode 50 which constitutes a variant of the cathode 32.

Fig. 9 represents a discharge tube comprising an incandescent cathode 51 and two plate-shaped anodes 52. When it is desired to de-gas these anodes 52 in the manner indicated above, this may be effected by means of a magnetic field 54 which is directed perpendicularly to the plates 52. By temporarily connecting the cathode 51 as an anode and the plates 52 as a cathode, the latter plates will be strongly heated, during which heating degassing may take place.

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