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Filed Sept. 28, 1938

Serial No. 232,237

2 Sheets-Sheet 1

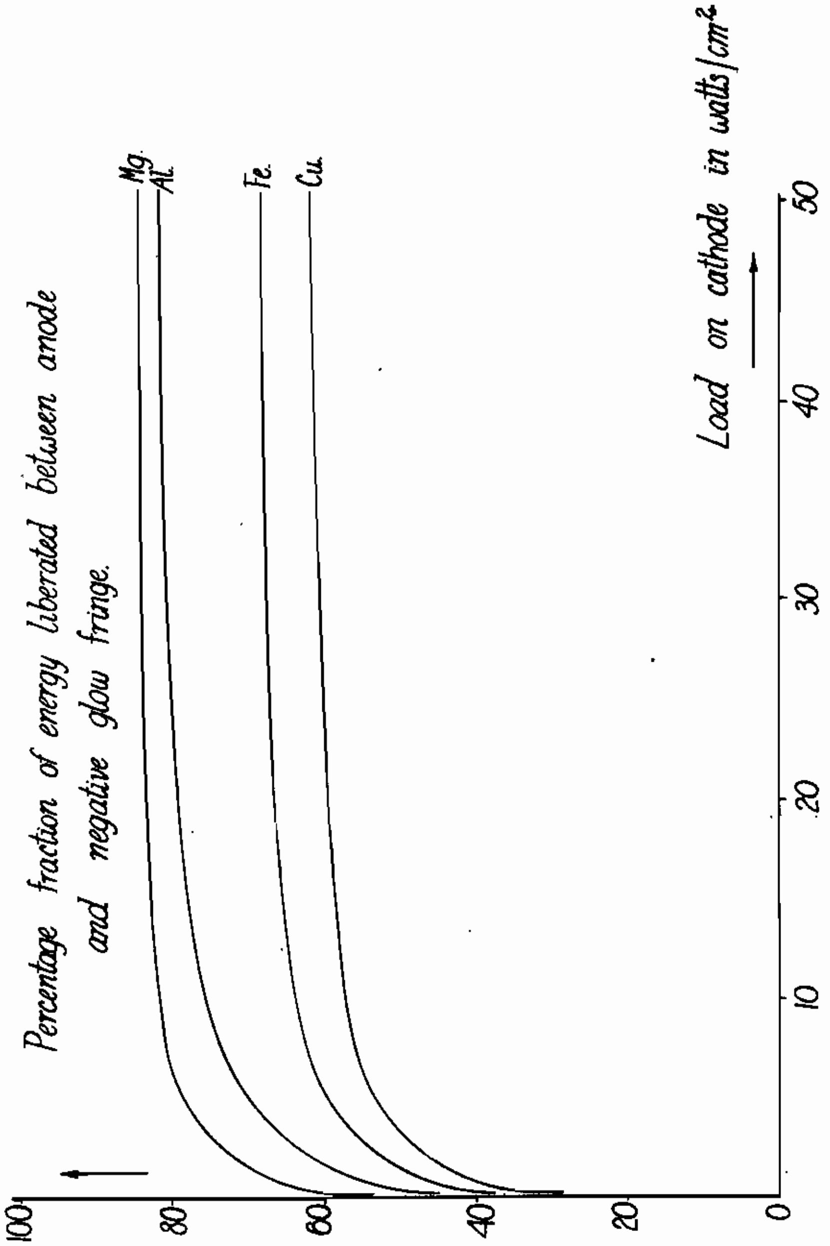

Fig. 1

B. Berghaus
W. Burkhardt
Inventors

By: Glascock Downing & Seebold
Attys.

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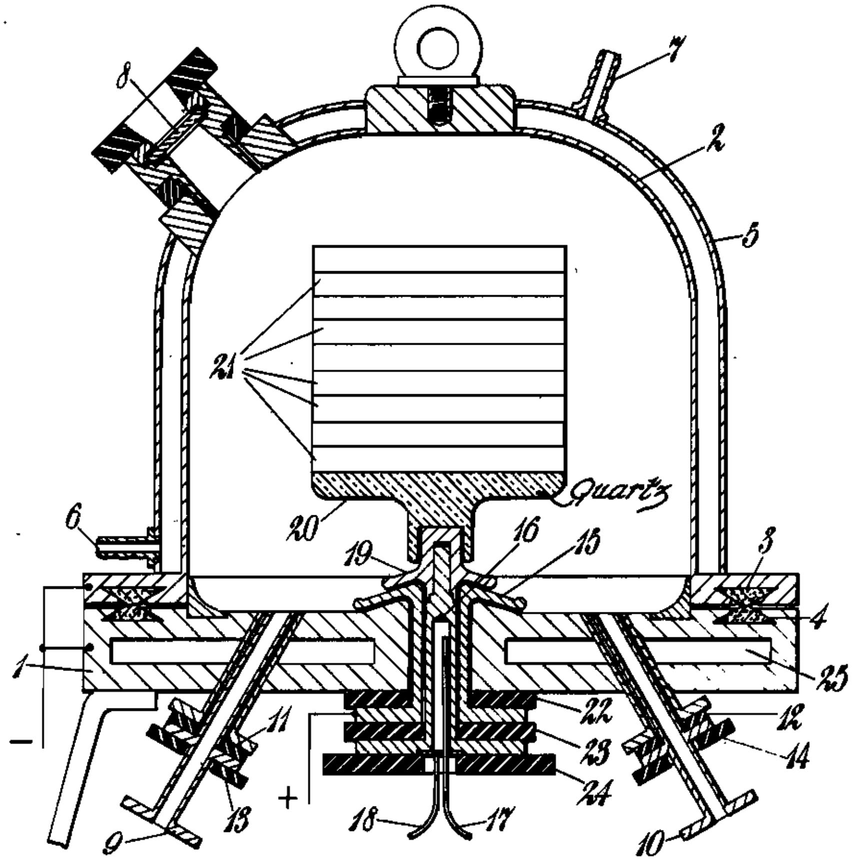

Fig. 2

B. Berghaus
W. Burkhardt
Inventors

By: Glascock Downing & Seebold
Attys.

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ALIEN PROPERTY CUSTODIAN

ELECTRICALLY HEATED VACUUM ANNEALING AND FUSION FURNACE FOR METALLIC AND NON-METALLIC MATERIAL

Bernhard Berghaus, Berlin-Lankwitz, and Wilhelm Burkhardt, Berlin-Grunewald, Germany; vested in the Alien Property Custodian

Application filed September 28, 1938

An apparatus is already known for producing high temperatures by means of cathode rays directed and united on to a small space, in which the cathode has for example the form of a hollow ball or a concave mirror. The cathode rays proceed outwardly from this hollow ball and are concentrated on the article to be heated, which may be neutral or connected up as anode. The wall of the known apparatus consists of glass. This known apparatus has it is true been used for scientific experiments, but it has not gained introduction into the arts, which is to be attributed to the liability to breakage on the part of the glass apparatus and the difficulties relating to the high vacuum necessary for producing cathode rays and the requisite high voltage of 20 to 300,000 volts.

An electric oven or furnace for heating articles to be introduced therein is also known in which the heat evolution of the negative glow, preferably in an attenuated gas atmosphere, more particularly an atmosphere of inert gases or other gases of low electro-negative character or a mixture of such gases, is used for the heating in such a way that the article to be heated either itself forms the negative electrode or is surrounded by it or is in good thermally conducting connection with it. In this connection it is known for the casing of the oven itself to serve as electrode, and in fact it may be connected up in circuit as anode and cooled. However, the casing of the known oven or furnace may also be connected up as cathode and the anode pass axially through the furnace in the form of a wire. This furnace also has not up to now gained introduction on a technical scale since it is not capable of handling the substantial electric outputs necessary in the technics, and the discharge, particularly at the insulators, readily strikes over into an undesirable arcing with the result that the gas discharge is upset and the heating has to be interrupted. These disadvantages are all removed by the present invention.

The present invention relates to an electrically heated vacuum annealing and fusion furnace or oven for metallic and non-metallic material which is distinguished by the fact that the wall of the oven or furnace is connected up wholly or partly as a cathode with respect to an insulated introduced anode. The material to be heated is arranged in the furnace electrically and thermally insulated. It rests either on an insulating plate or in a crucible of quartz, glass, porcelain or other ceramic masses or on a plate or in a crucible of metal or graphite, which is carried by a coolable lead-through arrangement. Preferably the wall of the furnace connected up as cathode consists of metal, preferably of iron or steel or still better of light metal or a light metal alloy. The oven wall connected up as cathode is in the case of short-period annealings or fusions constructed so as to be coolable. The oven wall connected up as cathode may however also be surrounded with a heat-insulating material, particularly for lengthy annealings. The oven wall connected up as cathode may consist of an electric semi-conductor, such as graphite or slate. The material to be annealed or fused may be in conducting connection with the anode or may itself form the anode. The pressure in the oven or furnace chamber preferably amounts to 10 to 0.05 mm., the voltage on the furnace chamber amounting to about 500 up to 7000 volts. The current cover per square centimetre of surface of the cathodically connected furnace wall preferably amounts to 0.5 to 100 mA. It may assume still higher values, however, if for example for sintering or fusing purposes temperatures are necessary up to 3000° C. and more. The insulated introduced lead-through element may be metallic and at the same time may be the current lead in for the anode, or, if the anode has a separate current lead, may consist wholly of insulating material, e. g. glass, quartz, ceramic masses, the insulated lead-through element likewise advantageously being cooled at its interior wall. The current lead in for the anode and the insulated introduced supports for the article or articles may advantageously be disposed concentrically. For the plate or the bed of the furnace or oven, upon which the articles rest, several supports, as described, may be passed in through the furnace wall.

For operating the furnace advantageously a direct voltage is used, the negative pole being on the housing and the positive pole on a separate, insulated, screened and cooled introduced anode; however, alternating voltage is also suitable if the effective surface of the introduced electrode is made very small with respect to the surface of the furnace housing, when a rectifying effect is produced. The current lead in for the anode is surrounded at a small distance by the cathode. The space advantageously forms a ring gap and protects the insulating material arranged behind the same from the impact of charge carriers from the gas discharge, as well as from particles disintegrated off the cathode, and the heat radiation. The insulating material which is behind the ring gap partly represents a prolongation of the same. The distance of the metallic jacketing of the current lead in for the anode into the gas space is to be chosen smaller than the distance of the glow fringe around the cathode. In practical operation a distance of 5 to 0.1 mm. has proved to be sufficient. It is essentially dependent upon the gas pressure and the voltage applied between the electrodes. It is advantageous to construct the gap in labyrinth form in order to prevent direct access of charge carriers from the discharge and disintegrated particles. In order to apply still higher voltages than 7000 volts the ring gap may be partly provided with an insulator, e. g. with quartz, glass, porcelain and so forth. The current lead in is conducted hollow and is cooled at its inner wall in order to protect the insulating means from heating.

The vacuum furnace described in more detail below depends upon a completely new method of converting electrical energy into heat, and the attenuated gas in the space between the glow fringe and the anode on applying a voltage serves as a resistance heating element which surrounds the material to be heated.

Experiments have shown that the energy supplied to a gas discharge when the "heating voltage" (referred to in German as "Brennspannung") is equal to the cathode drop, is completely converted into heat at the cathode and consequently no appreciable heat is liberated in the space between the glow and the anode. If on the other hand the "heating voltage" exceeds the cathode drop, there takes place a heating of the glow fringe/anode space which increases with the difference between the two voltage values. This difference can be produced by the following expedients: It has been found that by increasing the power of the gas discharge the proportion between the "heating voltage" and cathode drop increases (see curves, Figure 1). It has further been found, as is apparent from mutual comparison of the curves in Figure 1, that the ratio of the "heating voltage" to the cathode drop is the more favourable the more readily the cathode material emits. Further experiments have shown in confirmation that for example still better values are produced by light metals oxidised right from the start or light metals spontaneously oxidising during the operation. It has also been found that the form of the gas space between the glow fringe and anode is important for the ratio of "heating voltage" and cathode drop, and in fact the ratio of the "heating voltage" to cathode drop increases the greater the fraction of the space between glow fringe and anode, which is occupied by the article. If for example an article of metallic or non-metallic nature is introduced into this gas space then, corresponding to its size, the same assumes in certain time a maximum temperature which depends upon the energy applied. If the quantity of heat liberated at the cathode is not accumulated, but is continuously led away by means of cooling water, then for the heating of iron bodies of various sizes an economy for the furnace is obtained which increases with the size of the iron bodies.

Finally it has also been established that the degree of vacuum and the nature of the gas used have an influence on the ratio of "heating voltage" to cathode drop.

In a furnace of 6 litres capacity iron articles of various sizes were introduced and heated to a temperature of for example 1000°. With copper as cathode material and hydrogen as filling gas, at a pressure of 0.2 mm. of mercury an efficiency was obtained, in spite of the unfavourably chosen conditions, of 10% for 0.5 kg., 30% for 5.5 kg., and 40% for 11.5 kg.

The principle of the furnace or oven obviously depends upon the fact that the otherwise usual electric heating element in the form of wire spirals, silicon carbide rods or other materials is replaced by the attenuated gas. What has proved to be surprising in these experiments is that on the one hand the energy distribution between cathode and gas space increases with increasing watt load referred to the cathode surface, and that special cathode materials, which favour this distribution, have been ascertained; whilst on the other hand, that the ratio of cathode drop to "heating voltage" is always greater the more space the body to be heated or the furnace charge takes up in the furnace, the more therefore the interior resistance of the remaining gas space increases, whereby in the gas space between the glow fringe and opposite electrode by purely ohmic consideration consequently more of the input energy remains for the heating of the charge.

In an experimental oven or furnace having a chamber of 6 litres the following values were for example ascertained as regards the interior resistance:

Kg	i	U_b	W_i
			Ohms
0.5	2.66	1250	470
5.5	2.00	1650	820
12.0	1.5	3200	1270

The decrease in the cathode drop in spite of the increasing "heating voltage" is clearly apparent from the fall of the current strength.

As the ratio of anomalous current to normal current on the cathode, values were obtained in the experiments up to 2000-fold. When the furnace casing formed the cathode, then with a ratio of 160-fold a 12 kg. body of iron could already in one hour be heated to 1000° at a total energy of 7 kilowatts. However, heating to medium temperatures, for example 300 to 500°, could be obtained with far smaller values, e. g. 30 to 80 times the normal current. The ratio of anomalous current to normal current consequently depends upon the temperature of the articles to be heated or on the time in which a definite temperature is to be attained.

Since a temperature of 1300° or more can conveniently be attained, tempering, letting down, clean annealing, hardening or the like can be carried out in the oven or furnace in a protective gas atmosphere. The oven therefore offers the advantage that there is no oxidation or scaling of the surfaces of the work, which is a matter of importance, especially for molybdenum steels.

The oven or furnace also offers particular advantages for the fusion of readily oxidisable and highly melting metals, since it avoids oxidation by using an indifferent gas on the one hand, and on the other hand at the said subatmospheric pressures of about 1 mm. and less an extensive degassing of the melt is brought about.

In the accompanying drawing the invention is shown schematically in some detail in one constructional example, Figure 2 showing a section through an electrically heated vacuum annealing and melting oven or furnace for metallic and non-metallic material, in which the wall of the oven is connected up as cathode of a glow discharge with respect to an insulated introduced anode, and in which the material to be annealed is arranged electrically insulated in the oven, and in which the electrically heated gas between the cathodic glow fringe and the anode forms the heating element for the material to be heated. The vacuum annealing and melting oven consists of a lower part 1 and a removable upper part 2, which are connected together in vacuum-tight fashion by means of seals 3 and 4, and which individually or jointly form the cathode. The upper part 2, constructed for example in the form of a hood, is provided with a cooling jacket 5 to which a cooling medium may be supplied through the lead 6, which medium can be led off through the outlet 7. In the upper part an opening is also provided which is closed off by means of a viewing window 8. The insulated pipe connection 8 arranged in the lower part has connected to it a vacuum pump (which is not shown) by means of which preferably a pressure of 10.0 to 0.05 mm. of mercury can be adjusted The lower part 1 also possesses a pipe connection 10, likewise insulated with respect to the cathode. The parts 11 and 12 are insulating rings and the parts 13 and 14 are insulating and pressing-on rings. A pressure indicating appliance may be attached to the pipe connection 10, and through this connection 10 there may also be supplied a filling gas in regulated quantity by way of a regulating valve, which is not shown. According to the material being heated or annealed, as filling gas may be used an inert gas, such as argon, krypton, xenon, helium, or a reducing gas, such as hydrogen, hydrocarbons or the like. Nitrogen, ammonia or similar gases may also be employed if an action is intended on the for example metallic material being heated or annealed. Gases or vapours may also be supplied which bring about chemical actions on the material being heated. In the lower part 1 the anode 15 is also arranged, insulated and screened off, as well as the lead-through element 16 which is made hollow and to which a cooling agent may be supplied through the lead 17, and led off through the lead 18. Between the anode 15 and the lower part 1 of the vessel there is a narrow gap of labyrinth form which is so narrow that no glow discharge is possible in the gap. Also between the anode 15 and the lead-through element 16 there is a similar narrow gap of labyrinth form. By means of an insulated screening pin 19, the lead-through element 16 carries for example a quartz plate 20 on which the material 21 to be heated is disposed in an insulated manner. In place of the quartz plate 20, a fusion crucible for example of carbon or of ceramic material, such as beryllium oxide, or even of metal may also be provided for accommodating the material to be heated or fused. 22 and 23 are insulating rings and 24 is an insulating and pressing-on ring, which is pressed on by means of a screw arrangement not shown. 25 is a cooling duct to which a cooling agent can be supplied.

BERNHARD BERGHAUS.
WILHELM BURKHARDT.