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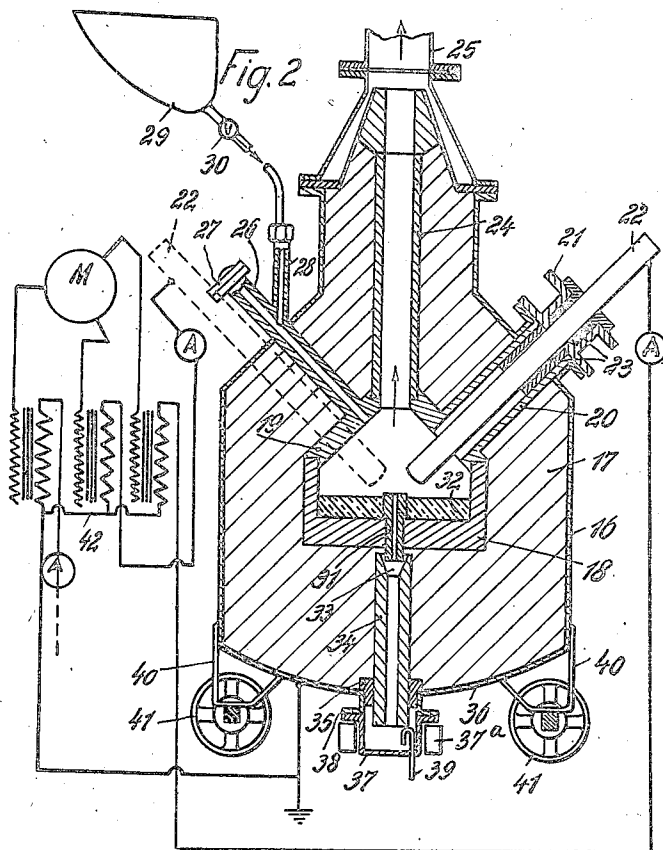
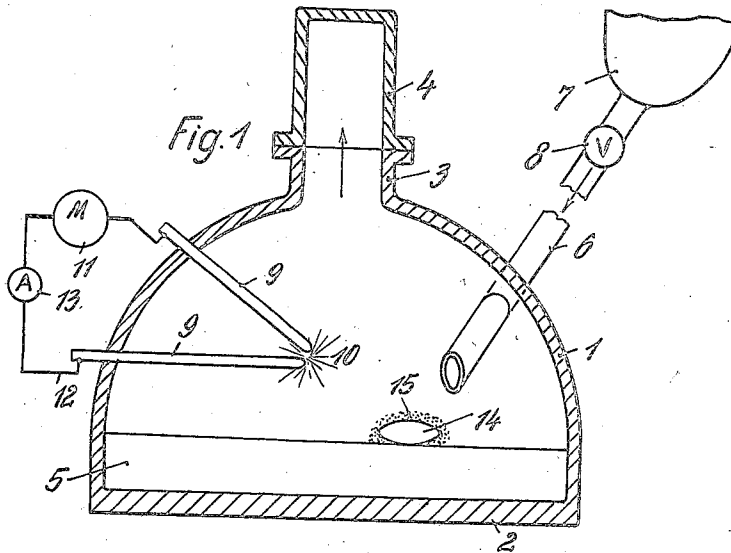
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2,207,746

APPARATUS FOR CONVERTING METALS AND THE LIKE

Filed June 7, 1937

3 Sheets-Sheet 1



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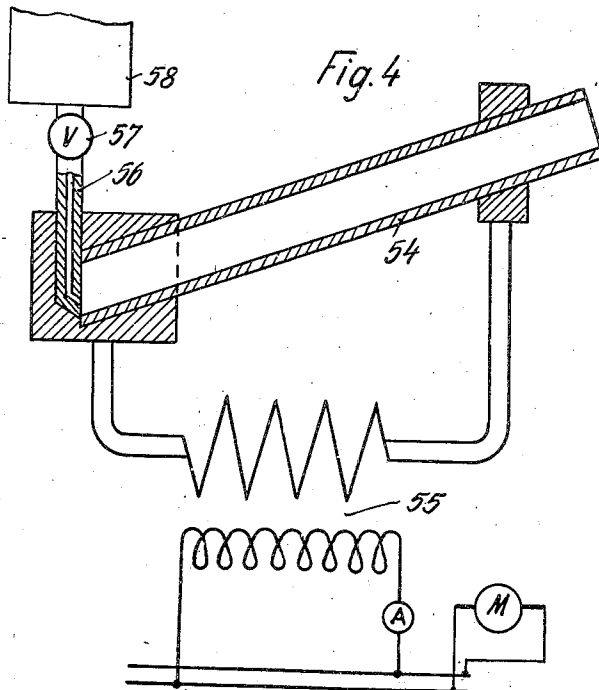
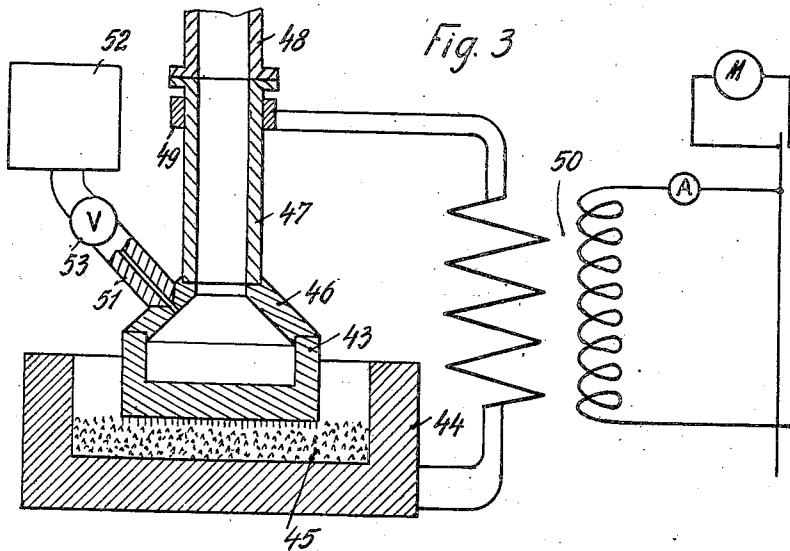
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3 Sheets-Sheet 2



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3 Sheets-Sheet 3

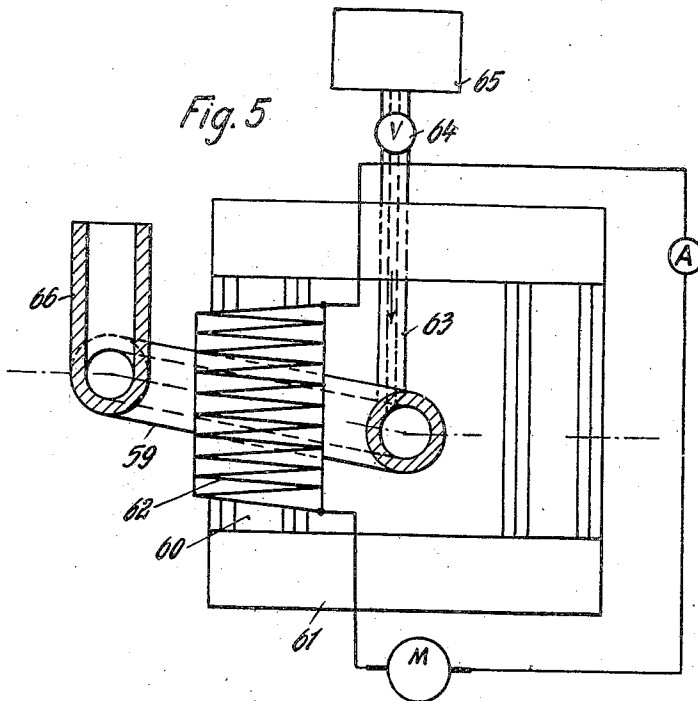
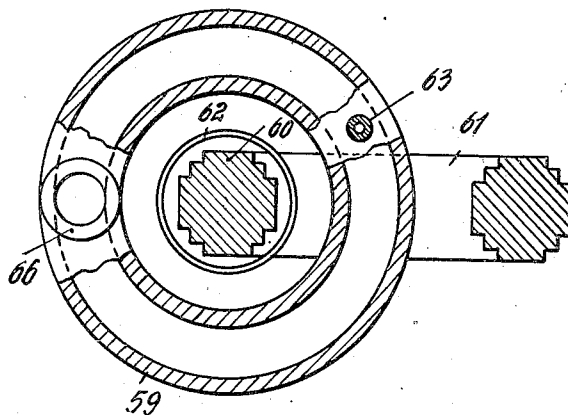


Fig. 6



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UNITED STATES PATENT OFFICE

2,207,746

APPARATUS FOR CONVERTING METALS
AND THE LIKE

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4 Claims. (Cl. 13—9)

The present invention relates to an apparatus for converting metals, metal alloys, metal compounds, as ores, or similar substances difficult to vaporize into the vapor state, to thereby render them either chemically unchanged or after dissociation or reaction with other substances suitable to be subjected to certain other processes, for instance precipitation in form of a very fine powder, decomposition in their components, separation of certain admixtures a. s. o. It has been found that the action of the new apparatus is far better than any apparatus known hitherto for obtaining a similar effect.

The invention is concerned with a furnace or crucible surface which is practically even and arranged substantially horizontal and which under no circumstances shows depressions and elevations allowing the formation of heap- or pond-like accumulations or collections of the particles to be treated.

A further object of the invention is to provide a novel apparatus in which such a high heat is caused to act upon the individual particles of the substance or upon small accumulations of same, that due to spontaneous vaporization these individual particles or small accumulations of same are completely surrounded by vapor originating from their substances. In this manner the well known Leidenfrost phenomenon appears. According to the present invention, this phenomenon appears when treating solid grains as well as liquid drops. With solid grains, this phenomenon results in this, that after an extremely short period of time these grains are, due to vaporization, invisible to the eye observing the interior of the furnace or crucible. When treating liquid drops, the Leidenfrost phenomenon besides causing lively vaporization results in very quick movements of the drops to and fro upon the vapor layer formed on top of the above described substantially even surface of the interior of the furnace or crucible.

It has also been found, that in the use of the new apparatus rectifier effects may occur. By means of a direct current indicator, connected in the circuit supplying current to the furnace or crucible, these effects may be observed and utilized for control purposes.

In the accompanying drawings, some constructions of crucibles according to the invention are shown by way of example.

In these drawings:

Fig. 1 is a diagrammatic sectional view of a crucible shown for explaining the principle of the invention,

Fig. 2 is a longitudinal vertical section through a crucible according to the invention,

Fig. 3 is a modified construction of a furnace according to the invention,

Fig. 4 shows a section through another modified furnace according to the invention,

Fig. 5 is a sectional view of a further modification of a crucible according to the invention, and

Fig. 6 is a horizontal section through the furnace shown in Fig. 5.

As shown diagrammatically in Fig. 1, the crucible 1, consisting of sheet iron, has a bottom 2 and is provided at the upper end with an outlet socket 3 which is connected with a chamber 4 for collecting the developed gases or vapors. The bottom 2 of the furnace 1 is covered by a plate 5 of graphite or the like the upper surface of which is substantially even, or at least so constructed as to prevent a greater accumulation or collection of particles or drops of the material or substances to be treated. A tube 6 extends through the walls of the crucible 1 and this tube is connected to a storage container or reservoir 7 for the material or substance to be treated. The tube 6 is provided with a shutoff valve 8. Moreover, two electrodes 9 pass through the walls of the crucible 1, and between these electrodes an electric arc 10 is formed in the interior of the crucible 1. A suitable source of current 11 is connected to the electrodes 9 by a circuit 12 in which an ammeter 13 is arranged.

The container or reservoir 7 is filled with granular material, if such material is to be treated, or the container is filled with liquid metal. By opening the shutoff valve 8 the material is fed into the furnace 1 in very small amounts at a time, preferably in form of individual grains or drops 14. In the very moment the drop 14 or the grain, introduced by way of the tube 6, reaches the plate 5 of the highly heated crucible 1, this grain or drop is completely surrounded by the vapor 15 developed in the crucible in such a manner, that said grain or drop in fact is somewhat lifted from the upper surface of the plate 5. Due to the fact that the drop 14 is surrounded by the vapor 15, the well known Leidenfrost phenomenon is obtained. The drop 14 then is quickly moved to and fro in the crucible 1. The developed vapors finally pass through the socket 3 of the crucible 1 into the chamber 4 from where they are conducted to any desired place of use. If granular material is to be treated, the same effect is obtained, if the material is fed into the crucible in such a manner as to reach the surface of the plate 5 in the form of individual grains.

Fig. 2 shows a construction of a crucible for practically carrying out the new process. In this construction, the casing 16, consisting preferably of sheet iron, is lined with a refractory material 17 in which the crucible 18 is embedded. The crucible 18 is closed at the upper end by a conical portion 19. Into the crucible 18 extend three tubes 20 one of which only is shown in the drawings for the sake of clearness. Each of the tubes 20 is fixed in position by means of a bracket 21 and serves the purpose of holding an electrode 22 which extends through the conical portion 19 into the interior of the crucible 18. In the drawing one of the electrodes 22 is shown in full lines, while the second one is shown in dotted lines only and the third one is not shown at all. Each of these electrodes 22 is, by insulations 23, electrically insulated with regard to the tube 20, the bracket 21 and the casing 16. From the conical portion 19 a tube 24 leads to a tube 25 which may be connected to a place of use for the gases or vapors developed in the interior of the crucible 18. Extending through the casing-wall 16, the refractory lining 17 and the conical portion 19 of the crucible 18 is a tube 26 the upper end of which carries a transparent plate 27 allowing observation of the interior of the crucible during operation. Exteriously of the casing 16 a tube 28 is provided which opens into the tube 26 and is connected to the storage tank or container 29 for the material to be treated. The tube 28 is provided with a control valve 30. Into the bottom of the crucible 18 a tube 31 is inserted which slightly extends over the upper surface of a plate 32 consisting of graphite or the like. The tube 31 is open at the upper end and its lower end is connected to a funnel-like opening 33 of a tube 34 extending through a bushing 35 and the bottom 36 of the casing 16 into a tank 37 fixed to a socket 38 of the bottom 36. A discharge tube 39 leads from the tank 37. Journalled in brackets 40 fixed to the bottom 36 of the casing 16 are wheels 41 allowing movement of the entire crucible from one place to another for the purpose of connecting same as desired to one or the other device in which the vapors of the metals, metal alloys etc. produced in the crucible, may be subjected to the desired treatments.

Should for any reason too great an amount of the material to be treated be fed at a time into the furnace or crucible 18 the surplus of material flows off by way of the tube 31 and reaches the tank 37 by way of the tube 34. The material may be discharged from the tank 37 through the tube 39 and used again in any suitable manner. The transparent plate 27 and the tube 26 allow observing of the interior of the crucible 18, and, therefore, of the operation of the latter, so that the feeding of the material to be treated from the storage tank or container 29 to the crucible may be controlled in any suitable manner.

If instead of granular material, liquid metal or metal alloys, for instance iron, are to be vaporized, the iron is fed into the crucible 18 preferably in form of a wire. The storage tank 29 and the valve 30 controlling the feed of the granular or liquid material or substance to be treated are then replaced by other devices which need not to be shown or described, as they are well known to men skilled in the art.

In some cases the devices controlling the feed of the substances to be vaporized may be so constructed, that they are automatically adjusted in accordance with the proceeding of the vaporization process. This control may for instance be

effected by means of relays operating in dependence on the temperature prevailing in the crucible, the electrical load, the level of the substance or other factors adapted to be indicated by measuring instruments.

The tube 34 may consist of graphite and is preferably heated by electric current to a suitable temperature. The tank 37 also is preferably heated. As those skilled in the art will readily appreciate, tank 37 may be heated by a gas flame, an auxiliary furnace, by an induction heater of the Ajax-Wyatt-Northrup type or the like 37A.

As mentioned already above, the upper surface of the plate 32 is preferably even. This plate, preferably consisting of graphite, is arranged in a horizontal plane and its upper surface may have small depressions which allow a limitation of individual drops of the liquid which, however, are so chosen, that heap- or pond-like accumulations or collections of a plurality of drops in one and the same depression are impossible.

The electrodes 22 are connected in star connection with the coils of a three-phase current transformer 42. The star-point is connected to the casing 16 of the crucible 18 and grounded. The primary current is supplied from a three-phase current line and its tension is controlled by control means well known in the art.

The electrodes may also be connected in another manner or be supplied with two-phase current or direct current. If desired one electrode only may be provided in which case the crucible 18 or the plate 32 serves as counter-electrode.

With certain of these connections rectifier effects may occur and, therefore, it may be preferable to connect an instrument, indicating and measuring direct current, in the circuit leading to the crucible 18.

If copper is to be vaporized in the apparatus according to the invention, the operation is as follows if the transformer has a capacity of 200 kilowatts.

When by switching on the current and forming the electric arc the furnace or crucible 18 is heated sufficiently high, liquid copper is fed into the crucible from the storage tank or reservoir 29 in an amount sufficient to cover the bottom of the crucible or the upper surface of the graphite plate 32, if such a plate is used, with a very thin layer of liquid copper. The electrical load is then increased so far, that the copper vaporizes which, as shown by experience, takes place slowly only as long as a coherent supply of liquid copper is present in the crucible. As soon as the liquid copper fed into the crucible is about exhausted and thereby the bottom of the crucible or the upper surface of the plate 32 begins to be free of copper to be treated, a surprising increase of the rate of vaporization results. Simultaneously the well known Leidenfrost phenomenon appears, that is to say, the greater and smaller drops still present are so quickly vaporized upon the plate 32, that they are somewhat lifted by the vapor from the plate. The individual drops are completely enveloped by vapor and are quickly moved to and fro in the crucible and finally splashed. Due to the extremely powerful heat radiation in the interior of the crucible, the drops are very quickly solved and vaporized, the the vapor is heated to a temperature far above the boiling point. This is still favored by the fact, that the vapors developed are compelled to flow through the electric arc.

As soon as the Leidenfrost phenomenon comes

to action and the vaporization starts, care is to be taken that fresh liquid copper is supplied to the crucible in an amount equal to that vaporized at a time in the crucible. If these conditions are maintained, the most favorable relations for the vaporization are obtained. The valve 30 controlling the feed of the material is of course, opened sufficiently wide for this purpose.

The fact that the Leidenfrost phenomenon comes to action simultaneously with a strong increase of the rate of vaporization is probably due to the fact, that the rest of the molten metal is thermally isolated from the bottom of the crucible by the metal vapor surrounding or embedding them. Consequently the heat supply by convection from the bottom decreases, but simultaneously also the withdrawal of heat, because the vapors are not as good a heat conductor as the liquid. Compared with their mass the isolated drops have a great surface and absorb great amounts of radiating heat the intensity of which in the hollow space of the crucible increases with the biquadrate of the absolute temperature, whereas the withdrawal of heat by convection increases slower with the temperature. It is immaterial whether or not the surprising increase in the rate of vaporization is caused by the Leidenfrost phenomenon. In any case the occurrence of the Leidenfrost phenomenon is a reliable criterion of the fact, that the crucible operates under correct conditions to obtain an intensive vaporization of the metal.

Other metals and metal alloys may also be vaporized by means of the described device, provided, that in the time unit so much of the substance to be vaporized only is fed into the vaporization space always as is vaporized in the same, and that the temperature of the space is maintained above that at which the Leidenfrost phenomenon begins to become effective.

The quantities or amounts of the substances to be treated and to be fed may be calculated from the thermal constants of the respective substance and the arc load. If the figures required for the calculation are only approximately known, they may be estimated and corrected during operation.

The device according to the invention may also be used for treating other substances, for instance metal compounds, as oxides, sulphides a. s. o., even if these substances are directly converted from the solid state into the vapor state.

The device according to the invention shown in Fig. 3 consists of a crucible 43 of graphite or the like which is heated by Joule heat. For this purpose the lower portion of the crucible 43 is embedded in a trough 44 consisting of conductive material which trough is filled with small coal 45. From the conical upper portion 46 of the crucible extends upwardly a tube 47 of conducting material which is connected to another tube 48. The upper end of the tube 47 is surrounded by a pipe clip 49 by means of which the current of a transformer 50 is conducted to the tube 47 forming the upper part of the crucible 43, so that the latter is intensively heated. A tube 51 connected to a storage tank or reservoir 52 and provided with a control valve 53 is connected to the upper part 46 of the crucible 43.

The operation of this device is similar to that described in connection with the construction shown in Fig. 2.

The crucible shown in Fig. 4 consists of a tube 54 of graphite or the like which is arranged in an inclined position and is also heated with Joule

heat by current of a transformer 55. A tube 56 provided with a control valve 57 is connected to the closed end of the tube 54 and to a storage tank or reservoir 58 for the material to be treated. With this construction also the temperature is raised to such a degree, that the material, fed into the device, splashes upon the hot wall of the tube 54, is converted into vapor and further superheated on the way to the discharge end of the tube 54 which may be connected to a place of use of the vapors. Due to the inclined arrangement of the tube 54 all drops not immediately vaporized roll back again and again until they are completely vaporized.

According to Figs. 5 and 6 the crucible consists of a hollow ring 59 of graphite or the like which surrounds a shank 60 of a transformer core 61 carrying the coil 62. The ring 59 forms the secondary coil and is, during operation of the transformer, traversed by heavy currents, with the result that the ring 59 is heated to very high temperatures. A tube 63 provided with a control valve 64 is connected to the ring 59 and to a storage tank or reservoir 65 for the material to be treated. The vapor produced in the ring 59 flows through the tube 66 and is led to a suitable place of use.

What I claim is:

1. A vapor-tight refractory apparatus for the vaporization of substances difficult to vaporize, including metals, metal alloys, metal compounds and the like comprising a crucible, the lower portions of the walls of said crucible forming an angle of not more than about 90° with the base of said crucible and the upper portions of said walls being convergent to provide a heat radiating surface, a substantially plane radiating and vaporizing surface disposed within the lower portions of said walls and substantially in contact therewith and in spaced relation with the aforesaid heat radiating surface to receive maximum practical heat radiation therefrom, said radiating and vaporizing surface providing a free unobstructed area and being constructed and arranged to prevent accumulations of a substance being treated in amounts greater than that which can be vaporized with manifestation of the Leidenfrost phenomenon, a vapor chamber over said vaporizing surface, an inlet duct in the convergent portion of said walls constructed and arranged to deliver a substance to be treated directly through the free space of said crucible to said vaporizing surface practically without contacting other surfaces, an outlet duct in the convergent portion of said walls constructed and arranged to provide heat radiation to said vaporizing surface from vapors passing to and entering said outlet duct, a plurality of electrodes disposed in the convergent portion of said walls, one electrode adjacent said inlet duct being in a vertical plane other than that of said inlet duct and said electrodes being of such length and so disposed as not to obstruct said vaporizing surface and not to inhibit the production of the Leidenfrost phenomenon, an outlet in said vaporizing surface adapted to remove liquid substance in excess of the amount capable of being vaporized, a tank for storing said excess liquid substance, a conduit connecting said liquid substance outlet with said tank, means for removing liquid substance from said tank, means for heating said conduit and said tank to a suitable temperature, and electric means only slightly greater than that required from theoretical calculations for supplying electric current to said electrodes

to heat said vaporizing surface to temperatures to which the Leidenfrost phenomenon occurs.

2. A mobile vapor-tight refractory apparatus for the vaporization of substances difficult to vaporize including metals, metal alloys, metal compounds and the like comprising a crucible, the lower portions of the walls of said crucible forming an angle of less than about 90° with the base of said crucible and the upper portions of said walls being convergent to provide a heat radiating surface, a radiating and vaporizing surface disposed in a substantially horizontal plane within the lower portions of said walls and in spaced relation with the aforesaid heat radiating surface to receive maximum practical heat radiation therefrom, said radiating and vaporizing surface having small depressions of such size as to preclude accumulations of a substance being treated in amounts greater than that which can be vaporized with manifestation of the Leidenfrost phenomenon and being constructed and arranged to provide a free unobstructed area, a vapor chamber above said vaporizing surface, a plurality of electrodes within said crucible including said vaporizing surface, electric means for creating an arc between at least two of said electrodes, said electric means being adapted to heat said vaporizing surface to a temperature at which the Leidenfrost phenomenon occurs and thereby vaporizing the substance being treated thereon, inlet means disposed in the convergence of said crucible for the introduction of material to be treated, said inlet means being disposed with relation to said electrodes to deliver a material to be treated to said vaporizing surface through a path in the free space of said crucible other than that of an arc created between said electrodes, outlet means disposed in said convergence for removing vapors of a material being treated, said outlet means being constructed and arranged to provide radiation to said vaporizing surface from said vapors passing to and entering said outlet means, means disposed in said vaporizing surface for removing excess of substance to be treated, a gas and liquid-tight reservoir having an outlet provided with a liquid seal for receiving said excess, means connecting said removing means and said reservoir, and means for maintaining the contents of said connecting means and said reservoir liquid.

3. A vapor-tight refractory apparatus for the vaporization of substances difficult to vaporize, including metals, metal alloys, metal compounds and the like comprising a crucible, the lower portions of the walls of said crucible forming an angle of slightly less than 90° with the base of said crucible and the upper portions of the walls being convergent to provide a heat radiating surface, a vaporizing and heat radiating surface disposed in a substantially horizontal plane within the lower portions of said walls and having its periphery in contact therewith and being in spaced relation to said heat radiating surface to receive heat radiations therefrom and adapted

to be heated to temperatures at which the Leidenfrost phenomenon appears, said vaporizing surface being constructed and arranged to prevent accumulations of a substance to be treated in amounts greater than individual particles including drops, electric means to heat said vaporizing surface to temperatures at which the Leidenfrost phenomenon occurs whereby a substance to be treated is rapidly vaporized, a vapor chamber over said vaporizing surface, inlet means in the convergent portion of said crucible constructed and arranged to deliver a substance to be treated directly and without impedance to said vaporizing surface through the vapor chamber of said crucible, outlet means in said convergent portion of said crucible constructed and arranged to provide radiation to said vaporizing surface from vapors passing to and entering said outlet means, gas and liquid tight means in spaced relation with said vaporizing surface for withdrawing and storing quantities of a substance to be treated in excess of that capable of being vaporized, and means for maintaining the contents of said withdrawal and storage means at a suitable temperature.

4. A vapor-tight refractory apparatus for the vaporization of substances difficult to vaporize, including metals, metal alloys, metal compounds and the like which comprises a crucible, the lower portions of the walls of said crucible forming an angle less than about 90° with the base of said crucible and the upper portions of said walls being convergent to provide heat radiation toward the lower portion of said crucible, a vaporizing surface disposed in a substantially horizontal plane within the lower portions of said walls and having its periphery in contact therewith, said vaporizing surface providing an unobstructed vaporizing surface for the manifestation of the Leidenfrost phenomenon and being constructed and arranged to prevent relatively large accumulations of a substance being treated, electric means for heating said vaporizing surface only slightly larger than that theoretically necessary for vaporizing particles or drops of a substance on said vaporizing surface with a manifestation of the Leidenfrost phenomenon, a vapor chamber in said crucible, means disposed in the convergent portion of said crucible for introducing a substance to be treated in a form of small particles or drops directly to said vaporizing surface through said vapor chamber, vapor outlet means disposed in said convergent portion of said crucible for removing vapors therefrom, said vapor outlet means being constructed and arranged to provide radiation from vapors passing to and entering said vapor outlet means to said vaporizing surface, means for removing substance being treated in excess of the amount which can be vaporized with a manifestation of the Leidenfrost phenomenon to a reservoir, means for removing a substance from said reservoir and means for heating said reservoir.

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