

Dec. 8, 1942.

R. MAIER

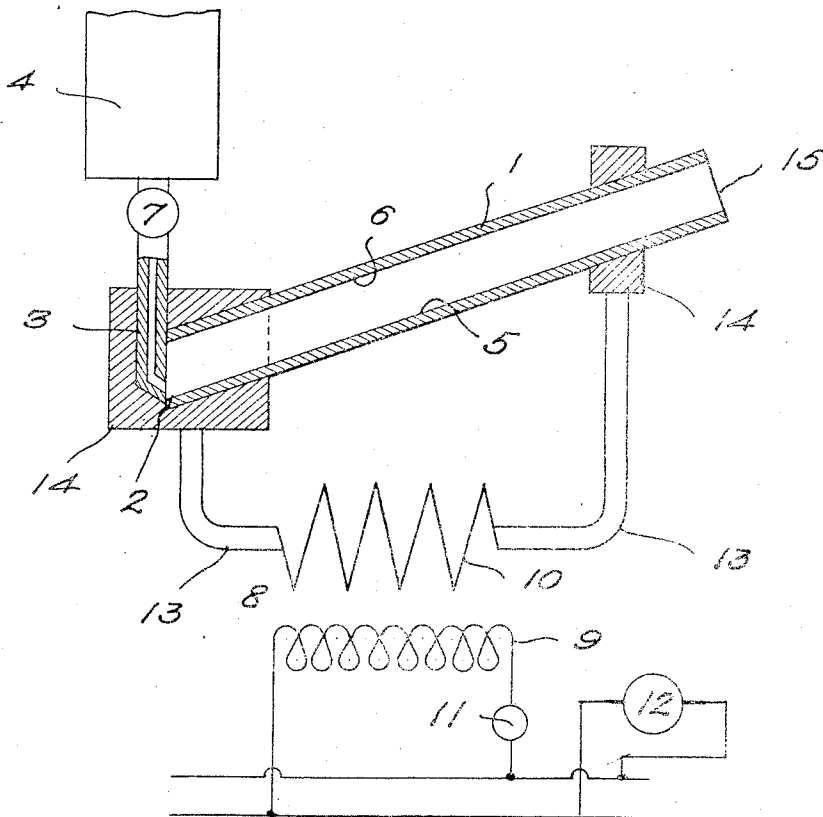
2,304,469

APPARATUS FOR CONVERTING METALS AND THE LIKE

Original Filed June 7, 1937

2 Sheets-Sheet 1

Fig. 1.



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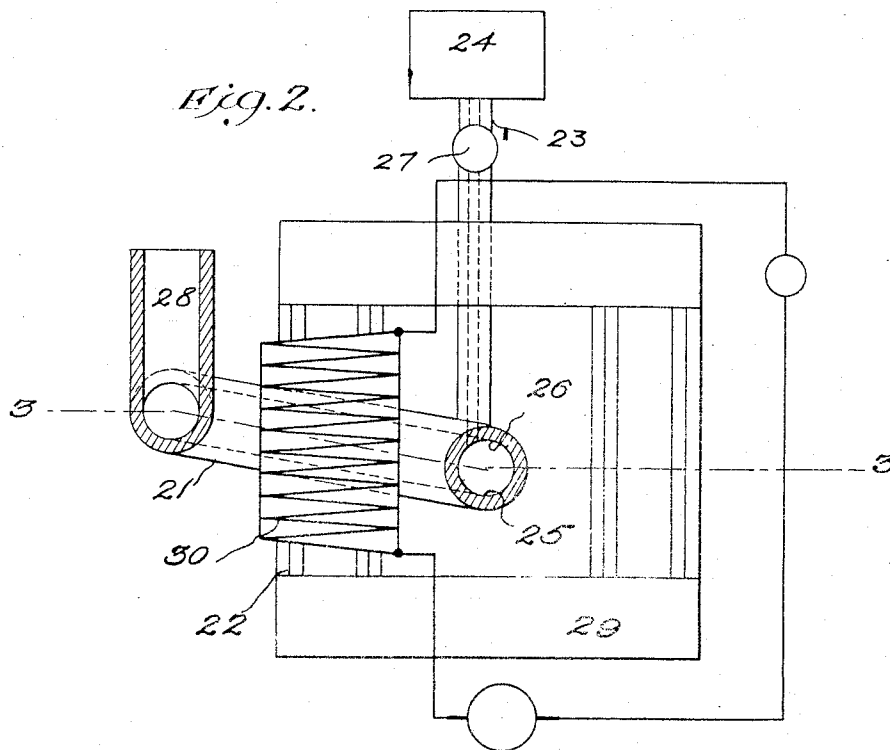
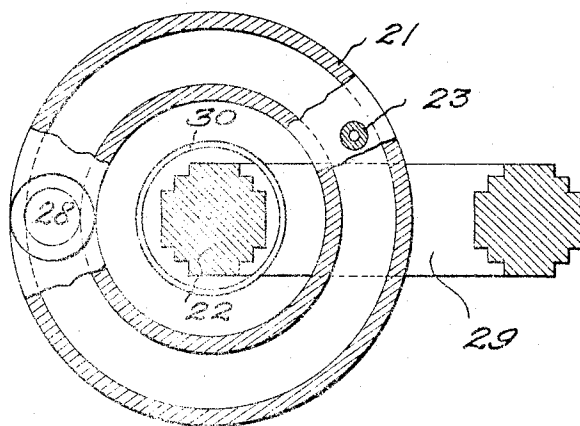


Fig. 3.



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APPARATUS FOR CONVERTING METALS
AND THE LIKE

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1936

2 Claims. (Cl. 13—28)

The present invention relates to an apparatus for converting metals, metal alloys, metal compounds and 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 other processes, for instance, precipitation or condensation in the form of a very fine powder, decomposition into their components, separation of certain admixtures and so forth. It has been found, that the action of the new apparatus is far better than any apparatus known hitherto for obtaining a similar effect.

It is an object of the invention to provide a furnace or crucible suitable for gasifying or vaporizing metals, metal alloys, metal compounds and the like difficult to vaporize wherein a vaporizing surface substantially devoid of depressions within which material to be vaporized may accumulate in the form of heaped-up or pond-like aggregations is procured.

It is another object of the present invention to provide a novel apparatus in which individual particles or small accumulations of particles of material to be vaporized or gasified are completely surrounded by vapor originating from the substance to be vaporized.

It is a further object of the present invention to provide a tubular crucible having a vaporizing surface of such character as to preclude substantial accumulations of the material to be treated into heaps or pond-like aggregations.

The present invention likewise contemplates the use of rectifier effects for control purposes. Other objects and advantages will become apparent from the drawings in which:

Fig. 1 is a vertical sectional view of an inclined tubular furnace embodying the principles of the present invention;

Fig. 2 is a vertical sectional view of another embodiment of the present invention; and

Fig. 3 is a horizontal section through the furnace shown in Fig. 2 at line 3—3.

Generally speaking, the apparatus of the present invention includes a container or reservoir which is filled with material to be treated in the crucible. The material in the reservoir may be in granular form, may be molten or may even be in the form of wire or other state of physical condition. The material to be treated and contained in the reservoir is fed in a regulated manner to a vaporizing surface within a refractory apparatus. Preferably the apparatus is air-tight and the vaporizing surface is con-

structed and arranged to provide a maximum of heat radiation to the material to be vaporized which is on the vaporizing surface. It is a feature of the apparatus of the present invention that the vaporizing surface within the crucible is of such character as to practically eliminate accumulations of material to be treated in larger aggregations than individual particles. That is to say, during the major period of operation the material to be treated is present on the vaporizing surface as small individual particles, and in such state of dispersion as to make possible a manifestation of the Leidenfrost phenomenon. As those skilled in the art know, materials which exhibit the Leidenfrost phenomenon are considered to be enveloped by a skin or film or mass of vapor evolved by the substance undergoing heating. The crucible and its vaporizing surface preferably are constructed of a heat conducting refractory material. For this purpose I have found graphite to be very satisfactory. The material to be treated is heated on the radiating and vaporizing surface which in turn is preferably heated by electric energy. This heating may be accomplished by resistance heating or the Joule effect or may be obtained by induction. The crucible or furnace is provided with a vapor outlet in close proximity to the radiating and vaporizing surface in order that there may be obtained the maximum heat radiation from the vapors of gasified material entering and passing through the vapor outlet to the vaporizing and heat radiating surface.

In order that those skilled in the art may have a better understanding of my novel crucible, the following description is given in conjunction with Fig. 1:

The crucible shown in Fig. 1 comprises a tube 1 of graphite or the like which is arranged in a position inclined from the horizontal. Tubular crucible 1 is provided at the lower end 2 with a tube 3 of refractory material. Tube 3 serves as a conduit to carry or guide material to be treated contained in reservoir or container 4 to the vaporizing surface 5 and radiating surface 6 of tubular crucible 1. Tube 3 is provided with a control valve 7 for regulating the amounts of material introduced into the crucible in accordance with the amount of material vaporized or gasified. Tubular crucible 1 is heated by resistance by a current from transformer 8 comprising primary winding 9 and secondary winding 10 and having the usual current measuring devices 11 and connected to a source of current such as generator 12. Conductors 13 are of the

type known to those skilled in the art and of the necessary size and capacity to transmit current from secondary winding 10 to refractory electrodes or contacts 14 preferably made of a refractory material such as graphite.

The crucible illustrated in Figs. 2 and 3 comprises a tubular annulus 21 of graphite or the like having a vaporizing and radiating surface 25 and radiating surface 26 which surrounds a shank 22 of a transformer core 29 carrying coil 30. The tubular annulus 21 forms the secondary winding of the transformer and is, during the operation of the transformer, traversed by heavy currents with the result that the tubular annulus 21 is heated to very high temperatures. An inlet tube 23 provided with control valve 27 connects the tubular annulus 21 with the storage tank or reservoir 24 within which the material to be treated is placed. The vapor or gasified material produced in the tubular annulus 21 leaves the crucible by means of outlet tube 28 likewise constructed preferably of a refractory material such as graphite.

Fig. 3 is a sectional view of the crucible illustrated in Fig. 2 taken on line 3—3 and the same characteristics designate the same elements of the crucible in Fig. 3 as in Fig. 2.

The operation of the crucible illustrated in Figs. 1, 2 and 3 involves filling the reservoir 4 or 24 with material to be treated. The material to be treated may be in granular form or the container may be filled with liquid metal. By opening the control valves 7 or 27, the material is fed into the crucible 1 or 21 in very small amounts at a time preferably in the form of individual grains or drops through tube 3 or 23. Simultaneous with the impinging of a grain or drop upon the highly heated vaporizing and radiating surface 5 or 25, the grain or drop is completely surrounded by vapor developed in the crucible in such a manner that the grain or drop is lifted to some extent from the heat radiating and vaporizing surface 5 or 25. Due to the fact that the drop or grain or particle is surrounded by a film or envelope of vapor, the well known Leidenfrost phenomenon is manifested. The drop or particle then is quickly moved to and fro on the surface 5 or 25. The evolved vapors finally pass from the crucible by means of outlet 15 or 28 into auxiliary apparatus where the vapors may be condensed or may enter into a chemical reaction.

Under some conditions it is advantageous to have the devices controlling regulation of the feed of material to the crucibles 1 and 21 automatically adjusted in accordance with the conditions existing in the crucible. 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. As mentioned hereinbefore, it is preferable that the heat radiating and vaporizing surface consist of a refractory material such as graphite. The upper surface of the heat radiating and vaporizing plate or surface may have small depressions which allow an accumulation of individual drops of the liquid but, however, are so chosen, that heap- or pond-like accumulations or collections of a plurality of drops in one end the same depression are practically precluded.

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

The crucible is heated to a temperature above the melting point of copper and liquid copper is fed into the crucible from the storage tank or reservoir. As soon as the copper is vaporized rapidly and simultaneously the well-known Leidenfrost phenomenon appears, that is to say, the greater and smaller drops present on the vaporizing surface are so quickly vaporized that they are lifted somewhat from the vapor plate, the individual drops are completely enveloped by vapor and quickly move to and fro in the crucible. Due to the extremely powerful heat radiation in the interior of the crucible, such as from radiating surfaces 6 and 26 and vaporizing and radiating surfaces 5 and 25, the drops are very quickly dissolved and vaporized and the vapor is heated to a temperature far above the boiling point. As soon as the Leidenfrost phenomenon comes into action and the vaporization starts, care is to be taken that the fresh liquid copper is supplied to the crucible in an amount equal to that vaporized at any one time in the furnace. If these conditions are maintained the most favorable relations for the vaporization and gasification of the material are obtained. The valves 7 and 27 controlling the feed of the material are of course opened sufficiently wide for this purpose.

The fact that the Leidenfrost phenomenon comes into action simultaneously with a strong increase of the rate of vaporization is probably due to the fact, that any particles of molten metal which may be present are thermically isolated from the bottom of the crucible by the metal vapor surrounding or enveloping them. Consequently, the heat supplied by convection from the bottom decreases but simultaneously also the withdrawal of heat decreases because the vapors are not as good a heat conductor as the liquid. Compared with their mass however, 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 bi-quadrade of the absolute temperature, whereas the withdrawal of heat by convection increases more slowly with the temperature. Nevertheless whatever may be the explanation it is immaterial whether or not the surprising increase in the rate of vaporization is caused by the Leidenfrost phenomenon. In any event, the occurrence of the Leidenfrost phenomenon is a reliable criterion of the fact that the crucible is operating under correct conditions to obtain an intensive vaporization or gasification of the metal. Other metals and metal alloys, metal compounds and the like may also be vaporized by means of the present invention provided, that in a unit of time only that amount of material to be vaporized is fed into the vaporization space as is approximately equivalent to the amount vaporized in the same unit of time and that the temperature of the vaporization 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 substances and the electric load. If the figures required for the calculation are only approximately known, they may be estimated and corrected during operation. The apparatus of the present invention may also be used for treating other substances, for instance metal compounds such as oxides, sulfides and so forth, even if these sub-

stances are directly converted from the solid state into the vapor state.

With the construction illustrated in Fig. 1, the temperature is raised to such a degree that the material fed into the crucible splashing upon the hot wall of the tube 1 is converted into vapor and superheated on the way to the discharge end 15 of tube 1 which may be connected to a means for condensing the vapors or to other apparatus in which further reactions may be carried on. Due to the inclined arrangement of tube 1, drops not immediately vaporized roll back again and again to the lower end 2 of tube 1 until they are completely vaporized.

The present application is a division of my co-pending application, Serial No. 146,748, filed June 7, 1937, now Patent #2,207,746.

Although the present invention has been described in conjunction with certain preferred embodiments thereof, those skilled in the art will readily understand that variations and modifications thereof may be made. Such variations and modifications are to be considered within the purview of the specification and the scope of the appended claims.

I claim:

1. A vapor-tight refractory apparatus for the vaporization of material difficult to vaporize, including metals, metal alloys, metal compounds and the like which comprises an inclined tubular annulus encircling one leg of a transformer and forming the secondary winding of said transformer, the lower arc of said tubular annulus forming a vaporizing and heat radiating surface and the upper arc of said tubular annulus forming a second heat radiating surface, an inlet duct disposed at the lower side of said inclined annulus for introducing material to be treated onto said vaporizing and heat radiating surface, an outlet duct disposed at the upper sides of said inclined

annulus for removing vaporized material, and electrical means including said transformer adapted to produce by induction electric currents in said tubular annulus of sufficient magnitude to heat said heat radiating and vaporizing surfaces to temperatures at which the Leidenfrost phenomenon is manifested, said tubular annulus being inclined sufficiently from the horizontal that at least a portion of the unvaporized material returns to the region of said inlet duct.

2. A vapor-tight refractory apparatus for the vaporization of material difficult to vaporize, including metals, metal alloys, metal compounds and the like which comprises an inclined duct-like annulus of refractory material encircling one leg of a transformer and forming the secondary winding thereof, a vaporizing and heat radiating surface comprising the internal surface of the lower section of said duct-like member, said vaporizing and heat radiating surface being constructed and arranged to prevent substance being treated accumulating in amounts substantially greater than individual particles, a second heat radiating surface comprising the remainder of the internal surface of said duct-like member constructed and arranged to radiate the maximum practical amount of heat to said vaporizing surface, means, disposed at the lower side of said annulus, for introducing substance to be treated onto said vaporizing surface, means for regulating the amount of substance introduced onto said vaporizing surface, means, disposed at the upper side of said annulus, for removing vaporized material, and electrical means including said transformer constructed and arranged to heat said heat radiating and vaporizing surfaces to temperatures at which the Leidenfrost phenomenon is manifested.

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