July 25, 1944. C. W. HEWLETT 2,354,521

EVAPORATOR FOR TREATING SURFACES

Filed Jan. 7, 1943 2 Sheets-Sheet 1

Fig. 1.

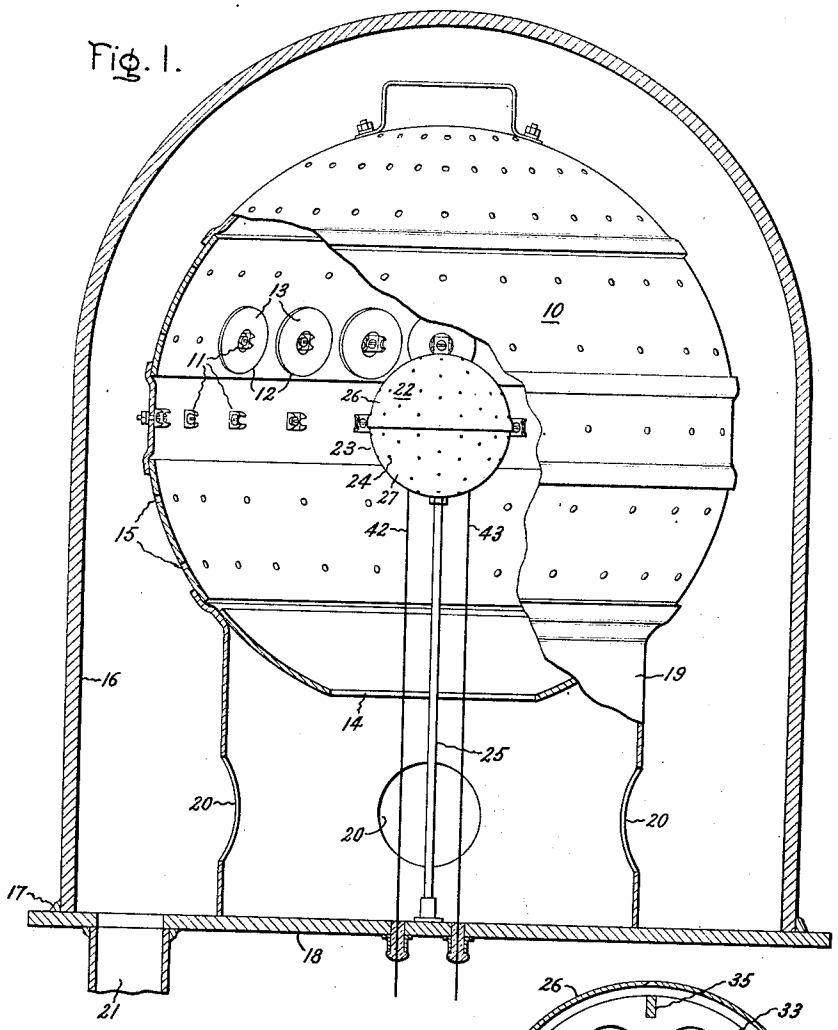


Fig. 2.

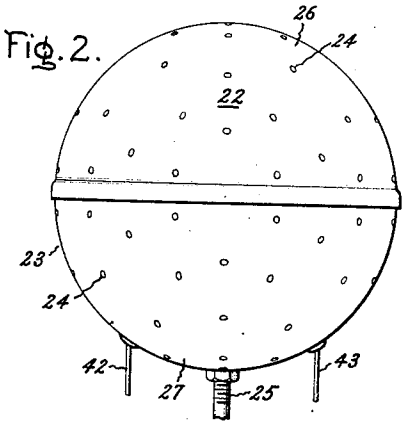
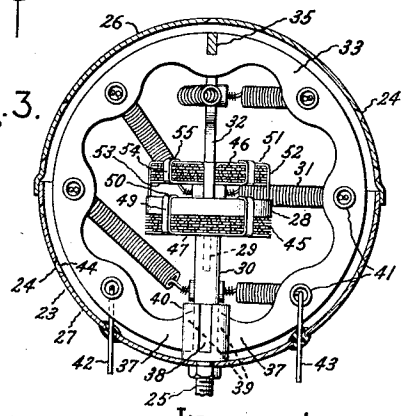


Fig. 3.



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Fig. 4.

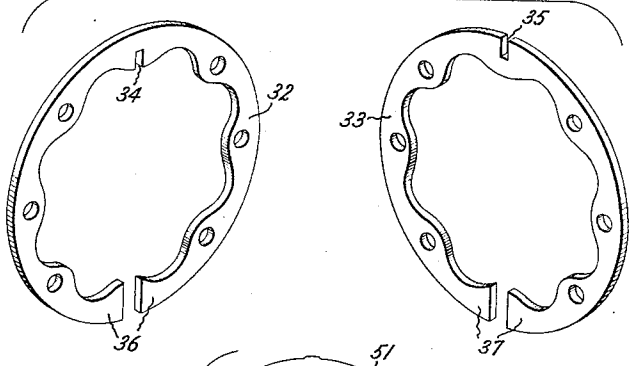


Fig. 5.

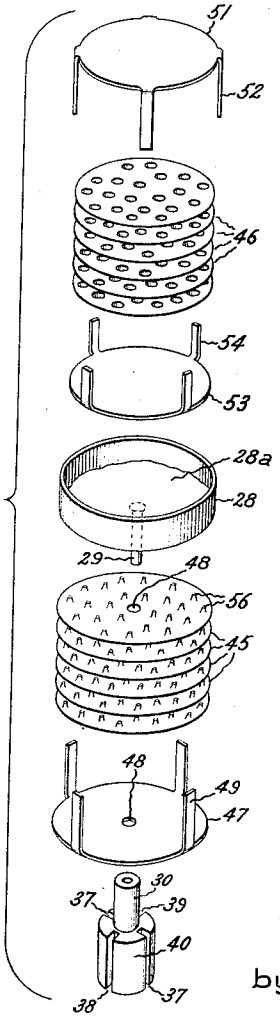


Fig. 6.

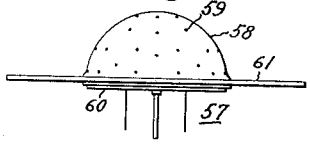
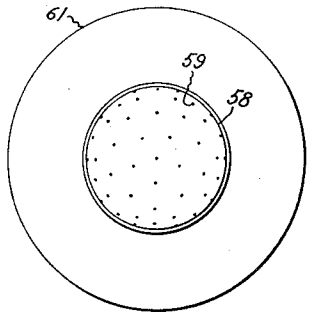


Fig. 7.



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UNITED STATES PATENT OFFICE

2,354,521

EVAPORATOR FOR TREATING SURFACES

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Application January 7, 1943, Serial No. 471,537

15 Claims. (Cl. 91—12.2)

My invention relates to an improved apparatus for depositing substances on a surface or surfaces, particularly for depositing vaporizable substances on a plurality of surfaces simultaneously.

One object of the present invention is to provide an improved apparatus for applying substances to surfaces by vaporization, such that the condensed deposit shall be of uniform thickness throughout its extent on the surfaces.

A further and particular object of my present invention is to provide an improved apparatus for insuring that the physical nature of the condensed deposit, that is, its state of crystallization, crystal orientation, compactness, and other characteristics, shall be of a high degree of uniformity throughout the extent of the deposit.

In my U. S. Patent 2,337,329, patented December 21, 1943, I have disclosed a means for obtaining by evaporation in a vacuum a condensed deposit upon a plurality of objects having flat surfaces. In accordance with the invention described in that prior patent, the objects upon which the vaporizable substance is to be deposited are attached to the interior surfaces of a spherical support in such manner that the flat surfaces to be coated are all tangent to an assumed single spherical surface concentric with the interior surface of the support. In an aperture formed in the bottom of the support an evaporator is fitted having a surface upon which the substance to be vaporized to the objects is placed, and a heater means is provided for the evaporator surface. The evaporator is so arranged that the surface of the substance to be evaporated is flat and of quite small area relatively to that of the assumed spherical surface to which the surfaces to be coated are tangent, and this surface of the substance to be evaporated is tangent to the assumed spherical surface.

Under proper conditions, by utilizing the apparatus of said prior patent, the surfaces of the several flat objects all receive deposits of the same thickness.

It has been found, however, that when articles are coated in the above-described apparatus, the physical nature of the deposit throughout the several surfaces to be coated may at times vary undesirably, for the reason, apparently, that the molecular rays proceeding from the evaporating substance which is located at the bottom of the spherical support, strike the several surfaces to be coated at widely different angles, and a difference in crystal structure of the deposit on the several surfaces, or a difference of orientation of the crystal aggregates, or both, may thereby result.

Further, if the surfaces to be coated have been roughened, as is desirable for certain purposes, the microscopic projections or protuberances of those of the receiving surfaces upon which the molecular rays make a large angle of incidence may at times tend to shadow or mask the adjacent microscopic valleys or depressions, and thereby to produce microscopic uncoated areas or spots in the depressions of the roughened surface.

In accordance with my present invention these difficulties are overcome and the above-mentioned objects, particularly the object of insuring uniformity of the physical nature of the deposit throughout its extent, are attained by providing, in place of the flat-surfaced evaporator located tangent to the spherical surface to which the several receiving surfaces to be coated are tangent, a spherical evaporator structure mounted within and concentric with the spherical support upon the inner surface of which the objects having the surfaces to be coated by vaporization are mounted.

In order that the uniformity of thickness and uniformity of the physical nature of the substance deposited by evaporation on the objects disposed about the interior surface of the spherical support at the center of which the evaporating substance is located, may be attained, the surface of the evaporator element from which the molecular rays are projected should be spherical. For most substances, however, the vapor pressure is not great enough for practical purposes in the process of depositing the coating by vaporization except at temperatures above their melting points. In the case of these substances, therefore, it is not practicable to attack the problem directly by attempting to provide a spherical mass of the evaporating substance, as this procedure would necessitate locating at the center of the spherical supporting surface upon which the objects are mounted, a spherical globule in liquid form of the substance to be evaporated.

On the other hand, if to overcome this latter difficulty it is proposed that a container or pan for the substance in liquid form be located at the center of the spherical support, then those objects mounted in the lower half of the support will receive little or no deposit and the density of the deposit on those objects in the upper half of the spherical support will be greatest at the top and will decrease toward the equatorial

region in proportion to the cosine of the angle between the vertical and a line joining the evaporating surface and the surface of the object receiving the deposit.

To overcome these difficulties in obtaining a spherical source of the molecular rays, I preferably provide in the center of the spherical support within which the objects to be coated are mounted an evaporator comprising a spherical shell, perforated for the passage of the molecular rays of vaporized substance, enclosing a pan or like holder or container charged with the vaporizable substance, and provided with means for supplying heat to maintain the shell at an elevated temperature and to melt and to evaporate the substance in the enclosed pan.

The heating means is preferably so arranged as to have no interfering or masking effect on the molecular rays which are projected radially from the outside surface of the evaporator. The construction materials for the various elements of the evaporator, for any given substance to be vaporized, must have a higher melting point than that of the substance, and must not be attacked by the vapor at its operating temperature. The perforations through which the vapor passes out from the spherical shell of the evaporator are so arranged that a substantially uniform distribution of the projected vapor is secured. To insure such a desired temperature relationship between the vapor, the evaporator shell, and the pan or holder together with the vaporizable substance placed therein, that the vapor will be supplied in sufficient quantity by the evaporator and its passage through the shell perforations will be unimpeded, a heat insulation means is provided associated with the pan or holder element.

The novel features which are considered to be characteristic of my present invention are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawings wherein Fig. 1 illustrates in partial section an apparatus for coating surfaces by vaporization embodying the present invention; Figs. 2 and 3 are enlarged views respectively of the exterior and interior of spherical evaporator structure employed in the embodiment of Fig. 1; Fig. 4 is an enlarged view of heater supporting elements; Fig. 5 is an exploded view on an enlarged scale of a pan or holder element for the substance to be vaporized together with heat shielding means for the holder element; and Figs. 6 and 7 illustrate in side elevation and plan view respectively a modification in which the evaporator structure is other than spherical, for example hemispherical in form.

In Fig. 1 the numeral 10 designates a spherical support the interior surface of which is provided with brackets 11 or like means for detachably holding in operative position any desired number of objects 12 such as rectifier electrode elements, for example, having flat surfaces 13 to be coated with a deposit produced by vaporization of suitable substances such as bismuth and selenium. The elements 12 are so mounted with reference to the spherical support 10 that the flat surfaces 13 are all tangent to an assumed spherical surface concentric with the interior surface of the spherical support. An opening 14, which may conveniently be located at the bottom of the spherical support 10, is provided therein, together with other openings such as perforations 15 in various parts of the support 10.

To permit the performing of the vaporizing process under vacuum conditions a bell jar 16 or the like surrounds the spherical support 10 and is joined by a temporary seal 17 to a floor plate 18. A cylinder or like member 19 having large openings 20 therein supports the spherical member 10 on the floor plate 18. To evacuate the interior of the bell jar and the spherical support 10 covered thereby a duct 21 is provided connected to a vacuum pump (not shown).

In the system disclosed in my above-mentioned prior patent the evaporator, employed in connection with a spherical support such as 10 for vaporizing a substance for the purpose of depositing a coating upon such surfaces as 13, comprises a heated flat-surfaced plate inserted in the opening 14. The surface of the substance placed on this plate in the vaporizing process was tangent to the assumed spherical surface to which the surfaces 13 are tangent. In the embodiment of my present invention illustrated in Fig. 1, however, the evaporator, designated generally by the numeral 22, comprises a spherical shell 23 having perforations 24 therein and mounted concentrically with the interior surface of the encircling spherical support 10 by a suitable standard 25 extending from the floor plate 18 to the evaporator.

As more clearly shown in Figs. 2 and 3, the latter figure being an enlarged interior view partially in transverse section of the enlarged perspective view of Fig. 2, the spherical shell 23 is preferably formed in two hemispherical sections 26 and 27 which are detachably fitted or hinged together. The evaporator encloses a pan or holder 26 (Fig. 5) to be charged with the substance 28*a* to be evaporated. The pan 28 is mounted centrally of the spherical shell 23 by means of a pin 29 extending downwardly therefrom into a supporting standard or stud 30 which is secured to the lower shell section 27.

Various means may be employed for supplying the heat required for vaporizing the substance in pan 28, for example, by induction, by electron bombardment, by radiation, etc. I prefer to supply the heat by radiation from a hot filament. The heating means in filament form may be arranged either outside or inside of the evaporator shell 23. I prefer, however, to place the heating means inside of the shell for greater economy of heat required, and further because this inside disposition of the heating means entails no shadowing or masking effect on the molecular rays as they are projected from the perforations 24 of the shell.

The heating element preferably takes the form of a bare metallic filament 31 or like element, which may be in coiled form as shown, or otherwise arranged. The heating element, coil 31, is distributed, as evenly as possible, near the entire inner surface of the shell 23 and thus surrounds the pan or holder 28 which is charged with the substance to be evaporated.

The heating element may be held in place within the shell by any suitable means, for example by suitable insulators on frame or supporting means which may be secured to the spherical shell or to a portion thereof. In the present embodiment of the invention the heater element mounting means comprises a pair of frame elements 32 and 33, shown separate from the shell in Fig. 4 for clearness, fitted together at right angles to each other by slots 34 and 35 and hav-

ing their lower ends 36 and 37 shaped to cooperate with pairs of slots 38 and 39 at right angles to each other and formed in a hub or enlarged portion 40 of the standard or stud 30 upon which the pan or holder 28 is mounted. The heating element 31 is secured to the two frame elements 32 and 33 by suitable insulators 41.

Two leads 42 and 43, insulated from the spherical shell 23 and passing therethrough, are connected to a source (not shown) of heating current for the element 31.

The heating element 31 for the pan 28 thus preferably takes such a general form as to be bounded on its outside by an assumed spherical surface of smaller diameter than that of the inside surface of the perforated spherical shell 23 and on the inside by an assumed spherical surface of larger diameter than that of the pan assembly.

The perforations 24 are preferably countersunk from the inside of the shell 23, as illustrated for example at 44, Fig. 3, so that they become sharply defined circular apertures, rather than channels, through which the vapor escapes from the interior of shell 23 to the region outside of the latter shell.

While the number of spaced perforations 24 in the shell 23 required to produce a substantially uniform distribution of the vapor after it has traveled a short distance from the evaporator may vary over a considerable range, I have determined that when the number is of the order of ninety-two for a shell 23 of suitable diameter a desired substantial uniformity of vapor distribution is obtained. A larger number of perforations may be employed but the perforations of necessity will then be of smaller diameter and more difficult to produce.

The positions of the perforations 24, a portion of which are indicated in Figs. 1, 2 and 3, may be determined as follows: (1) locating twenty of them at the vertices of the regular dodecahedron which may be assumed to be inscribed in the shell 23, (2) after laying out these twenty perforations which occupy a pentagonal array on the spherical surface, twelve other perforations are located at the center of each spherical pentagon, (3) each pentagon then is divided into five similar spherical triangles and (4) a perforation then is located at the center of each of the sixty triangles. While the resulting ninety-two perforations 24 are not rigorously uniform in distribution over the surface of shell 23 their location is satisfactory for practical operation.

In order that the vapor may escape from all of the equal perforations 24 in shell 23 at the same rate it is necessary that the vapor pressure within the shell 23 be the same at all points of the interior surface of the latter shell. For this reason, the combined area of the perforations 24 must be small compared to the unperforated area of the shell 23 and must also be small compared to the area of the surface of the evaporating substance with which pan 28 is charged. If the latter requirement is met, the other requirement, that the total perforation area be small compared to the shell area, is also met. I have found that satisfactorily uniform deposits on the objects to be coated are obtained by so determining the size of the perforations 24 for a given number thereof that their combined area is of the order of one-ninth that of the pan 28.

The pan 28 and the vaporizable substance 28a contained therein must be maintained at a temperature such that the vapor pressure of the substance is high enough to cause the required amount of vapor to escape through the perforations 24 in a reasonable time, and at the same time the shell 23 must be maintained at a temperature high enough to prevent the condensing of vapor on its inner surface and consequent clogging of the perforations. The temperature of the shell 23 should therefore be maintained slightly higher than that of the substance being vaporized in the pan 28, and this requirement is achieved in accordance with my invention by providing the pan 28 with an adequate amount of heat shielding so that the heat flow into the pan, at a temperature appreciably below that of the shell 23, is equal to the latent heat carried off from the substance by the evaporation.

For the latter purpose the pan 28 is partially enclosed by heat-shielding or radiation-reducing means comprising, for example, a series of stacked elements or plates 45, which may be of any suitable material, as aluminum for low temperature operation or thin molybdenum for high temperatures, mounted below the pan, and a similar series of plates 46 above the pan, these metals providing bright metal reflecting surfaces aiding materially in the radiation of heat.

The lower shield plates 45 are mounted between the bottom of pan 28 and a base plate 47. Centrally disposed openings 48 (Fig. 5) are formed in the plates 45 and 47 through which passes the pin 29. To hold the shield plates 45 in position the base plate 47 is provided with upwardly extending arms 49 which are bent over the upper edge of the pan 28 to form hooks 50 (Fig. 3).

The upper shield plates 46 are placed between a top plate 51 having downwardly extending arms 52 and a bottom plate 53, the latter having upwardly extending arms 54 which are bent over the edge of the top plate 51 to form hooks 55. To hold the assembly of shield plates 46 in position above the pan 28 and spaced upwardly thereof a suitable distance to permit the flow of vapor therefrom the downwardly extending arms 52 of the top plate 51 are formed straight, and of proper length to rest upon the bottom surface of the pan when the upper shield plates 46 are in operating position.

The shield plates 45 and 46 are spaced a short distance axially of each other. If formed of metal the plates may be spaced by forming short projections 56 thereon, as best shown in Fig. 5, by a suitable stamping or like operation.

In a typical practical example of the system described herein in accordance with my present invention for forming a deposit by vaporization, during a given period of operation of the system 2.5 grams of bismuth constituting the charge placed in the pan 28 is required to be evaporated, and deposited upon the surfaces of objects such as flat rectifier elements spaced over a spherical interior surface, such as that of support 10, which is two feet in diameter. Bismuth has a reasonably high vapor pressure at 800° C. The metal parts of the evaporator 10 are preferably constructed of molybdenum since it is not attacked by either liquid or vaporous bismuth at the temperatures above mentioned.

The pan or holder 28 may be approximately 0.75 inch in diameter since the 2.5 gram charge of melted bismuth is adequately held in a container of this size. The heating element 31, of coiled filament form, is so arranged as to be contained within a space, between pan 28 and spherical shell 23, of one inch internal diameter and one and one-half inch outside diameter, and the shell element 23 is therefore of one and three-

quarters inch minimum diameter in order adequately to house the heating element 31 without danger of contact between the two metallic elements.

Since the spherical shell 23 is required to be maintained at approximately 1100° C. and the outside area of the shell is 9.4 sq. in., a power input to the shell of 230 watts is required, which is supplied by the heater element 31. If the heater element were assumed to be constituted by an unenclosed straight wire at a temperature of 1300° C., the required power would be supplied if the area of the wire were 4.6 square inches. However, the space within shell 23 actually available for the heater 31 permits the employing of 60 inches of 0.033 inch diameter wire, having a surface area of approximately six square inches, which is in practice sufficient to prevent the temperature of the wire, when radiating 230 watts, from rising above 1300° C., even though the wire is in coil form and is surrounded by the shell 23. Further, this temperature, 1300° C., is sufficiently low to insure that the molybdenum heater wire will not be attacked by the bismuth vapor.

Since the diameter of the pan 28 is 0.75 inch and since the combined area of the 92 perforations 24 is preferably one-ninth of the area of the pan, the diameter of each perforation is approximately 0.026 inch.

The determining of a suitable number and thickness of the spaced plates constituting the heat shielding elements 45 and 46 is in a large measure a matter of trial and error. For use in connection with the evaporator 22 having the 0.75 inch diameter pan 28 evaporating 2.5 grams of bismuth at each charge in the 1.75 inch diameter shell 23, the assemblies 45 and 46 each comprise eight circular sheets of molybdenum approximately 0.001 inch in thickness.

The typical practical apparatus in accordance with my invention, constructed and operated as hereinabove described, produced upon the objects spaced over the interior surface of the spherical support, a deposit of uniform thickness and having a satisfactorily high degree of uniformity of physical nature throughout the extent of the deposit on the several objects.

The evaporator structure 22 as hereinabove described is capable of and is illustrated as arranged for the projecting of the vapor from the substance in pan 28 in substantially all directions, so that rectifier carrier electrodes 12 or like objects may be placed in all parts of the spherical support 10, and, when so placed throughout the support, will receive a uniform condensed layer of the evaporated substance. In certain applications of my invention it is desired to project the vapor toward only a limited portion of a holder such as spherical support 10, thereby to form a deposit upon electrodes or like objects located only in this limited portion of the holder. If the evaporated substance is to be deposited over objects on a hemispherical surface only, as for example over objects located only on the upper hemisphere of spherical support 10, then perforations, of suitable diameter, number and spacing may be formed only in the upper half of the evaporator shell, omitting the perforations in the lower half to avoid using more of the evaporated substance than necessary. A vapor-reflecting or baffle means may be provided associated with the evaporator shell to prevent more completely the molecular rays from being projected uselessly into the lower and unused portion of the spherical support.

As illustrated in Figs. 6 and 7, which represent an embodiment of the invention wherein the vapor is to be projected from perforations in an upper hemisphere only of an evaporator, I prefer to dispense entirely with that portion of the evaporator not provided with perforations. In Figs. 6 and 7 the evaporator, as designated generally by the numeral 57, then assumes the form of a hemispherical shell 58 having perforations 59 therethrough, and having, instead of a hemispherical lower portion, a cover or base plate 60 removably hinged or fitted to the shell 58. Suitable pan or holder means for the substance to be evaporated and heater and heat shielding means for the holder may be provided within the evaporator structure, essentially as in the embodiment of the invention illustrated in Figs. 1 to 5.

The hemispherical shell 58 is provided with a vapor-reflecting or baffle member constituted preferably by a collar or annular plate 61 in close contact with the shell 59 at its base or lower edge. The plate 61 is arranged to be heated sufficiently, as by conduction from any suitable heating means preferably within the evaporator, to prevent condensation, on the latter plate, of vapor projected from the perforations in the shell 59. The heated annular plate 61 may extend out from the lower edge of shell 59 nearly to the interior wall of the support, as 10 of Fig. 1, upon which the objects to be coated are mounted. However, in practice it has been found that the plate 61, to ensure substantial uniformity of the condensed deposits, need extend out only approximately one-third of this distance.

My invention has been described herein in particular embodiments for purposes of illustration. It is to be understood, however, that the invention is susceptible of various changes and modifications and that by the appended claims I intend to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States, is:

1. An apparatus comprising the combination of an evaporator shell, at least a portion of which has the general shape of a portion of a sphere and having perforations therein, a holder within said shell adapted to contain a substance to be vaporized, heating means operatively associated with said shell and said holder for projecting vapor of such substance through said perforations, and means for supporting objects having surfaces to be coated in such relation to the vapor-emitting perforations of said evaporator that the surfaces to be coated are substantially equidistant from said vapor-emitting perforations.

2. A condensing apparatus comprising the combination of a spherical support for objects upon which vapor is to be condensed, an evaporator therein comprising a shell, a holder within said shell adapted to contain a substance, and heating means within said shell for evaporating said substance, said shell having perforations formed therein for the projecting of the vapor of said substance therefrom, the total area of said perforations being small relative to the area of said substance to be evaporated.

3. A condenser apparatus comprising a spherical support, an evaporator enclosed therein comprising a shell, a holder within said shell adapted to contain a substance to be vaporized and means for vaporizing said substance, said shell containing perforations which are internally countersunk to facilitate outward flow of vapor therethrough.

4. A condenser apparatus comprising the com-

bination of a spherical holder, an evaporator located therein comprising a spherical shell, a holder therewithin for containing a vaporizable substance, and heating means for vaporizing said substance, said shell having relatively small perforations of the order of ninety two in number formed therein and spaced substantially uniformly thereover for projecting the vapor of said substance uniformly exteriorly of said shell.

5. An apparatus for depositing vaporizable material on receiving surfaces comprising a perforated spherical shell, a holder mounted within said shell adapted to contain a substance to be vaporized, a heating element located in the space between said shell and said holder, a spherical support for objects to be coated surrounding said shell and being spaced away from and substantially parallel to the exterior surface of said perforated shell.

6. An evaporator comprising a perforated shell, a holder spaced centrally of said shell containing a substance to be vaporized, a heating element located in the space between said shell and said holder, a frame within said shell in rigid connection therewith, means to mount said heating means insulatingly on said frame, and a support for object to receive deposits symmetrically located within vapor-depositing distance external to said evaporator.

7. An evaporator comprising a perforated but otherwise closed shell, a holder within said shell for containing a substance to be vaporized, heating means in said shell, and radiation shielding means located between said holder and said heating means.

8. An evaporator comprising a shell, a holder within said shell containing a substance, a heater enclosed within said shell, and a plurality of relatively thin plates interposed between said heater and said holder for retarding the rate of heat flow into said substance from said heater.

9. An evaporator comprising a shell having perforations therein, a holder within said shell containing a substance to be evaporated, heating means between said shell and said holder, and means for retarding the rate of heat flow from said heating means to said substance comprising two groups of radiation shielding elements disposed on opposite sides of said holder and spaced from each other to permit escape of the vapor of said substance to said perforations.

10. The combination of an evaporator comprising a shell, a portion at least of said shell having the general form of a portion of a sphere, said shell having perforations therein for the projecting of vapor therefrom, a holder within said shell adapted to contain a substance to be vaporized, heating means within said shell to vaporize said substance thereby to project said vapor through said perforations and means for supporting spaced equidistant about said evaporator a plurality of objects in unimpeded vapor-receiving position.

11. An apparatus for coating the surfaces of a plurality of objects with a deposit comprising a housing constituting part of a sphere, brackets for attaching the objects to be coated to the interior surface of said housing, an evaporator having a spherical shell concentric with said interior surface, and means within said evaporator shell for forming the vapor of said substance, said shell having a plurality of perforations formed therein for the projection of said vapor radially toward said surfaces of the objects to be coated.

12. An evaporator comprising a hollow shell having a portion generally hemispherical in form, said shell having perforations only in said portion thereof for the projection of vapor from the interior of said evaporator, a vapor-reflecting member operatively associated with said shell portion for preventing said vapor from being projected in undesired directions from said evaporator, and a support for articles to be coated which includes a hemispherical enclosure for said evaporator which is spaced away therefrom, said enclosure being substantially concentric with the hemispherical vapor-projecting shell of said evaporator.

13. An evaporator comprising a hemispherical shell having perforations therethrough for the projection of vapor from the interior of said evaporator, a baffle plate in contact with and surrounding the base of said shell and extending a substantial distance from said shell radially thereof and a support for articles to be coated which includes a hemispherical enclosure for said evaporator and is spaced away therefrom, said enclosure being substantially concentric with the hemispherical, vapor-projecting shell of said evaporator.

14. The combination of means for supporting a plurality of objects in such relation that surfaces to be coated shall constitute a composite surface having substantially the configuration of a segment of a sphere, an evaporator comprising a perforated hollow body having a surface configuration which is symmetrical with respect to said composite surface and which is symmetrically spaced from said objects, and means enclosed by said hollow body for projecting vapor of a chosen coating material through the perforations of said evaporator upon said surfaces.

15. An apparatus for producing coatings by condensation of vapor comprising a perforated, substantially spherical evaporator shell, a holder spaced centrally of said shell containing a substance to be vaporized, a heating element located in the space between said evaporator shell and said holder, a frame within said shell in rigid connection therewith, means to mount said heating means insulatingly on said frame, substantially spherical support for articles to be coated, said support being spaced away from and substantially parallel to the exterior surface of said evaporator and a sealed envelope which is adapted to be evacuated enclosing said elements.

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