July 12, 1966

S. WITZ

3,260,235

APPARATUS FOR COATING MATERIAL WITH METAL

Filed July 25, 1961

3 Sheets-Sheet 1

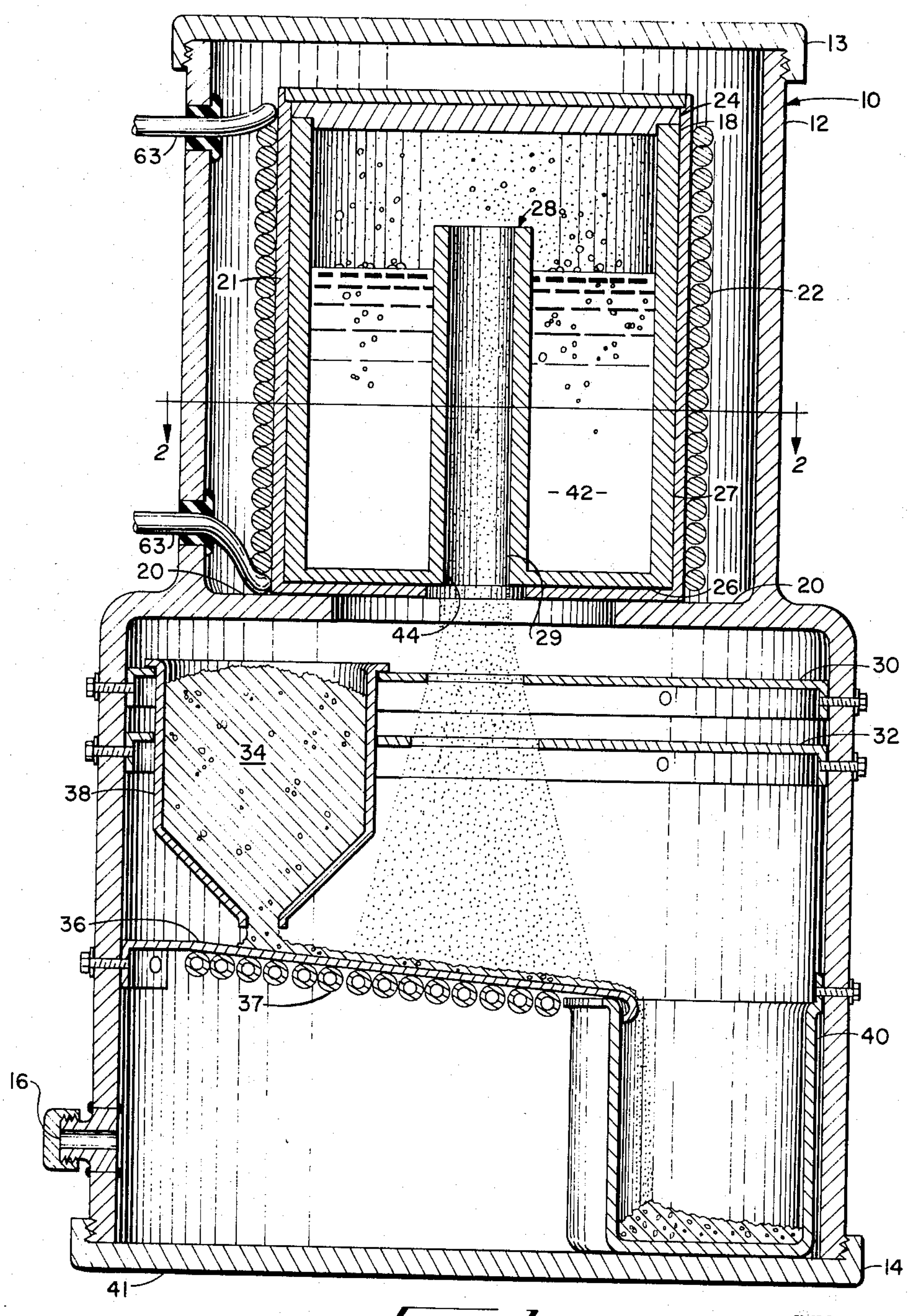

Fig-1

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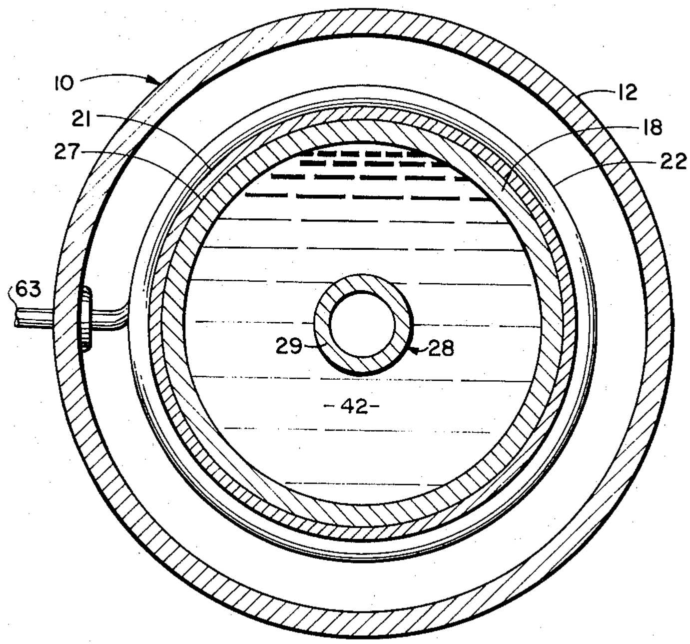

Fig-2

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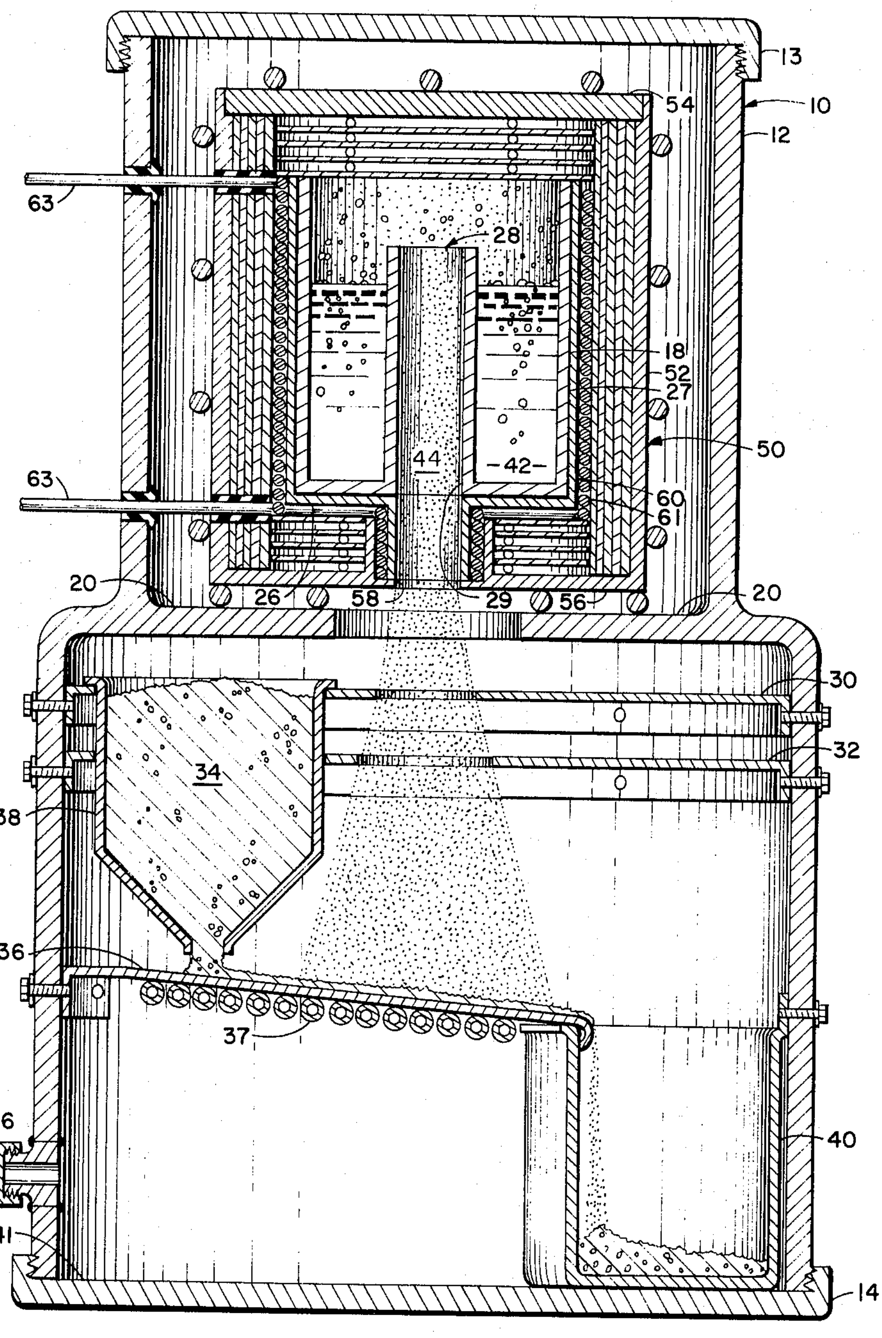

Fig-3

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APPARATUS FOR COATING MATERIAL WITH METAL

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7 Claims. (Cl. 118—49.1)

This invention relates generally to furnaces and more particularly to a crucible used in furnaces for the vaporization of metal.

The high temperature heating of metal in a vacuum has found application in the vaporization of the metal for depositing a metal film on various kinds of material. More recently, it has been discovered that the performance and handling characteristics of certain rocket propellants are improved if they are coated or encapsulated in a metal such as aluminum. In particular, it has been found that an oxidizer such as ammonium perchlorate has better chemical and handling characteristics when coated with aluminum vapor.

However, furnaces previously designed for vaporization of metals have proven unsatisfactory. The reason is that high energy rocket propellants such as ammonium perchlorate are highly reactive and are sensitive to the contact of hot metal droplets thereon. When the prior furnaces were used to vaporize metal for encapsulating particles of high energy propellants, it was found that there was a tendency for the metal vapor to condense into droplets on leaving the furnace. This created a danger of explosion. Consequently, it was necessary to treat smaller quantities of the high energy propellants in each operation in order to limit the consequences of a possible explosion. This was economically wasteful.

What is needed, therefore, and comprises an important object of this invention is to provide a heating furnace which eliminates premature condensation of the metal evaporant before the material being encapsulated had been coated.

The invention in its broadest aspect comprises positioning a crucible inside of a heating device. The crucible is provided with an upper wall, a lower base, and connecting side walls. The base is provided with an upwardly extending outlet tube mounted therein. The outlet tube is in spaced relation to the walls of the crucible and in concentric therewith. This crucible is mounted above the material to be coated and a series of collimating plates are placed therebetween. The crucible and the material to be coated are mounted inside of a vacuum chamber. With this arrangement when the heating device is energized, the crucible is heated. The metal inside the crucible quickly melts and its vapor passes out of the crucible through the centrally-disposed downwardly open outlet tube. The vapor is then directed against the material to be coated or encapsulated.

This and other objects of this invention will become more apparent when read in the light of the accompanying specification and drawings wherein:

FIG. 1 is a side sectional view of an induction furnace with a crucible constructed according to the principles of this invention mounted inside;

FIG. 2 is a sectional view taken on the line 2—2 of FIG. 1; and

FIG. 3 is a side sectional view of a resistance furnace with a crucible constructed according to the principles of this invention mounted inside.

Referring now to FIG. 1 of the drawing, the apparatus indicated generally by the reference numeral 10 includes an outer housing 12. The housing 12 is provided with upper and lower access closures 13 and 14 to provide access to the interior thereof. In addition, the housing is

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provided with a vacuum outlet tube 16 which is adapted to be connected to a vacuum pump (not shown) to evacuate the interior of the housing.

A crucible indicated generally by the reference numeral 18 for the melting and vaporization of metal is mounted inside the housing an conventional supports 20. The crucible is preferably cylindrical in shape although its precise shape is not critical and others such as rectangular, spherical, etc. are contemplated. As shown, the crucible is mounted inside of an aluminum oxide shell 21 to prevent heat losses. The aluminum oxide shell in turn is mounted inside a conventional induction coil 22.

The crucible includes an upper wall or lid 24, a base 26, and connecting cylindrical side walls 27. A vapor beam outlet tube 28, concentric with and spaced from the walls of the crucible extends upward from the base 26 to a level higher than the depth of the metal to be melted in the crucible. A series of collimating plates 30 and 32 are positioned below the crucible 18 for reasons to become apparent below. For induction heating of non-ferrous metals, the crucible is preferably formed from graphite because of its conductivity. The crucible could also be formed from tantalum or tungsten if desired.

A downwardly inclined guide or support member 36 is positioned below the outlet tube 28 and the collimating plates 30 and 32. The collimating plates are adapted to direct the vapor beam from outlet tube 28. The support member is cooled by conventional cooling coils 37 connected to a cooling source (not shown) for reasons to become apparent below.

A conventional hopper 38 is mounted at the upper end of the inclined support member 36 on collimating plate 30. The hopper discharges material 34 to the upper end of the guide or support member at a predetermined rate. A receiving container 40 is positioned at the lower end of the support member 36 on the bottom 41 of the housing 12 to receive the material 34 leaving the support member.

In operation, when a high frequency current on the order of 15,000 c.p.s. is passed through the induction coil, metal such as aluminum particles inside the crucible, will be rapidly melted to produce molten aluminum 42 because current induced in the graphite crucible heats the crucible and this heat is conducted to the material inside. Since the crucible is mounted inside a vacuum chamber, the aluminum vapor boiling off the surface of the melted aluminum will pass down through the outlet tube 28 where it is again heated by the hot walls 29 of the outlet tube 28. The walls 29 of tube 28 are heated both by induction and by conduction from the heat conducted to them from the surrounding liquefied metal, thereby preventing the vapor from condensing.

The position of the outlet tube 28 is rather critical because if the outlet tube touches or is very close to the walls of the crucible, the outlet tube will not be heated uniformly, and a certain portion of the aluminum vapor will condense into droplets. When the material being encapsulated or coated is a high energy propellant ingredient such as ammonium perchlorate, the contact of these droplets on the particles of the propellant could cause an explosion.

However, by positioning the outlet tube 28 close to the center of the crucible, it has been found that the tendency of the aluminum vapor to condense in the outlet tube and cause an explosion or clog the tube, is greatly reduced. In addition, the metallic vapor leaves the crucible 18 through exit 44 of the outlet tube 28 in a comparatively narrow, easily controlled beam. This vapor beam is directed through collimating plates 30 and 32 which have the dual effect of controlling the distribution of the vapor over the material to be coated and directing the vapor beam against the guide or support member **36**.

With this arrangement, if the hopper **38** is filled with particles of high energy propellant ingredients **34**, such as ammonium perchlorate, or other material to be encapsulated, this material is deposited on the upper end of support member **36**. Then the material gravitates down the support member into the path of the vapor beam. Since the guide or support member **36** is cooled by cooling coils **37**, the particles of material are cooled in turn, so that the vapor contacting these cooled particles condenses thereon and encapsulates it.

Under some circumstances, it may be desirable to use a resistance furnace **50**, as shown in FIG. 3 as the heat source for vaporizing metal for the encapsulation of high energy propellants. The resistance furnace **50** is mounted inside the evacuated housing **12** and associated with the same auxiliary equipment as the induction furnace shown in FIG. 1. In the embodiment shown, the resistance furnace comprises side walls **52**, a removable access closure **54** and a base wall **56**. The base wall **56** is provided with an opening **58** extending therethrough for reasons to become apparent below.

The walls of the furnace are formed from a heat resistant heat insulating material such as tantalum sheets held together by molybdenum rings. An inner cup **60** formed from a material such as aluminum oxide is mounted inside the furnace, and high resistance wires **61** connected to power leads **63** are positioned between the outer walls and base of the cup **60** and the inner surfaces of the walls and base of the furnace **50**. The crucible **18** is mounted inside the cup **60**. With this arrangement, cup **60** isolates the side walls **27** and base **26** of the crucible **18** from the high resistance wires **61** to prevent any possible chemical reaction therebetween. The opening **58** in the base **56** of the furnace **50** is concentric with the exit opening **44** of the outlet tube **28** in the crucible **18**.

With this arrangement, when material such as aluminum **42** inside the crucible is melted, a vapor beam from the liquefied metal leaves the furnace and crucible through the outlet tube **28** and the opening **58**.

On leaving the outlet tube **28** and passing through the opening **58**, the vapor beam confined by collimating plates **30** and **32** is directed against the cooled downwardly inclined support member **36**, as described in connection with the induction furnace. The particles of high energy propellant ingredients **34** leaving the hopper **38** inside housing **12** gravitate down the support member **36** into the path of the vapor beam where they are cooled and encapsulated by the vaporized metal deposited thereon.

Although the present invention has been shown associated with induction and resistance heating devices, it is to be understood that the principle of this invention can be practiced with other types of furnaces which can supply sufficiently high temperatures without contaminating the material being treated.

It is to be understood that the forms of the invention herewith shown and described are to be taken as preferred examples of the same, and that various changes in the shape, size, and arrangement of the parts may be resorted to without departing from the spirit of this invention or the scope of the claims.

I claim:

1. An apparatus for coating material with aluminum comprising in combination a housing, a closure for said housing to provide access to its interior, means for evacuating the interior of said housing, a generally cylindrical graphite crucible mounted in said housing, said crucible including an upper wall, a lower base, and connecting cylindrical side walls, an induction coil wrapped around said crucible, said induction coil adapted to be connected to a high frequency source of electric power, an outlet tube extending up through said base to a level higher than the liquid level of the aluminum to be melted in said crucible, said outlet tube concentric with and in spaced

relation to the cylindrical side walls of said crucible, a plurality of collimating plates positioned below the outlet tube in said base of the crucible for controlling the spread of the aluminum vapor beam exiting through the outlet tube when the induction coil is in operation, a downwardly inclined material support member, a hopper mounted in said housing at the upper end of said material support member for depositing a controlled stream of material thereon, and a container positioned at the lower end of said material support member for receiving material leaving said material support member, whereby material deposited on the upper end of said material support member gravitates toward the lower end thereof and passes through the aluminum vapor beam directed against said material support member so that aluminum vapor is deposited on said material and the aluminum coated material is collected in said container.

2. An apparatus for encapsulating high energy propellant particles in metal comprising an induction furnace for vaporizing metal, said induction furnace comprising in combination a housing, a closure for said housing to provide access to the interior of the housing, means for evacuating the interior of said housing, a generally cylindrical graphite crucible mounted in said housing, said crucible including an upper wall, a lower base, and connecting cylindrical side walls, an induction coil wrapped around said crucible, said induction coil adapted to be connected to a high frequency source of electric power, an outlet tube extending up through said base to a level higher than the liquid level of the metal to be melted in the crucible, said outlet tube concentric with and in spaced relation to the cylindrical side walls of said crucible, a plurality of collimating plates positioned below the outlet tube in the base of the crucible for controlling the spread of the metal vapor beam exiting through the outlet tube when the induction furnace is in operation, a downwardly inclined guide member, said collimating plates directing said metal vapor beam against said guide member, a hopper mounted in said housing at the upper end of said guide member for depositing a controlled stream of particles of a high energy propellant thereon, and a container positioned at the lower end of said guide member for receiving said particles of high energy propellant leaving said guide member, whereby the particles of high energy propellant deposited on the upper end of said guide member gravitate toward the lower end thereof and pass through the metal vapor beam directed thereagainst so that metal vapor is deposited on said particles of high energy propellant and the metal coated particles are collected in said container.

3. An apparatus for encapsulating high energy propellant particles in metal comprising in combination a housing, a closure for said housing to provide access to the interior of the housing, means for evacuating the interior of said housing, a resistance furnace mounted in said housing, a crucible mounted in said resistance furnace, said crucible including a lower base and side wall means, an outlet tube extending up through said base to a level higher than the liquid level of the metal to be melted in the crucible, said outlet tube concentric with and in spaced relation to the side wall means of said crucible, and collimating means positioned below said outlet tube and defining a path in vertical alignment therewith for substantially confining the vaporized metal leaving said crucible through said outlet tube to a relatively narrow metallic vapor beam for direction against particles of high energy propellant, whereby condensation of the vaporized metal prior to contact with the particles of high energy propellant is substantially reduced.

4. An apparatus for encapsulating high energy propellant particles in metal comprising in combination a housing, a closure for said housing to provide access to the interior of the housing, means for evacuating the interior of said housing, a resistance furnace mounted in said housing, said resistance furnace including a removable

closure, side walls, and a base, said base having an opening extending therethrough, a cup in said resistance furnace, high resistance wires mounted between the outer walls of the cup and the inner walls of the furnace, a crucible mounted in said cup, whereby the high resistance wires are chemically isolated from said crucible to prevent a chemical reaction therebetween, said crucible including a lower base and side wall means, an outlet tube extending up through said crucible base to a level higher than the liquid level of the metal to be melted in the crucible, said outlet tube concentric with and in spaced relation to the side wall means of said crucible and concentric with the opening in the base of said resistance furnace, a plurality of collimating plates positioned below the outlet tube in the base of the crucible for controlling the spread of the metal vapor beam exiting through the outlet tube when the resistance furnace is in operation, a downwardly inclined guide member, said collimating plates directing said metal vapor beam against said guide member, a hopper mounted in said housing at the upper end of said guide member for depositing a controlled stream of particles of a high energy propellant thereon, and a container positioned at the lower end of said guide member for receiving the particles of high energy propellant leaving said guide member, whereby the particles of high energy propellant deposited on the upper end of said guide member gravitate toward the lower end thereof and pass through the metal vapor beam directed thereagainst so that the metal vapor is deposited on said particles of high energy propellant and the metal coated particles are collected in said container.

5. An apparatus for coating material with metal comprising a housing, a closure for said housing, means for creating a vacuum in said housing, a crucible mounted in said housing and adapted to contain metallic material, means for heating said crucible to maintain the metallic contained therein in a molten state such that metallic vapor is formed, a vapor outlet tube extending up through the bottom wall of said crucible within said crucible to a level higher than the liquid level of the metallic material to be contained in said crucible for discharging metallic vapor from said crucible therethrough, collimating means positioned below the vapor outlet tube and said crucible within said housing and defining a path in vertical alignment with said outlet tube for substantially confining the metallic vapor discharged from said crucible through said outlet tube relatively narrow metallic vapor beam whereby condensation of the metallic vapor prior to contact with the material to be coated is substantially reduced, support means within said housing positioned below said collimating means and in registration with the outlet tube to lie in the path of the metallic vapor beam, means for feeding material onto said support means such that the material is movable along said support means across the metallic vapor beam, and means for cooling said support means so that the metallic vapor deposited on the material moving along said support means is condensed thereon.

6. An apparatus for coating material with metal as defined in claim 5, wherein said support means is downwardly inclined, said material feeding means comprising a hopper mounted above said support means at the upper end thereof for depositing a controlled stream of material thereon, and a container positioned below said support means at the lower end thereof for receiving material leaving said support means, whereby material deposited on the upper end of said downwardly inclined support means gravitates toward the lower end thereof passing through the metallic vapor beam to become coated with metal and being collected in said container.

7. An apparatus for coating material with metal comprising a housing, a closure for said housing, means for creating a vacuum in said housing, a crucible mounted in said housing and adapted to contain metallic material, means for heating said crucible to maintain the metallic material contained therein in a molten state such that metallic vapor is formed, a vapor outlet tube extending up through the bottom wall of said crucible within said crucible to a level higher than the liquid level of the metallic material to be contained in said crucible for discharging metallic vapor from said crucible therethrough, collimating means positioned below the vapor outlet tube and said crucible within said housing and defining a path in vertical alignment with said outlet tube for substantially confining the metallic vapor discharged from said crucible through said outlet tube to a relatively narrow metallic vapor beam whereby condensation of the metallic vapor prior to contact with the material to be coated is substantially reduced, support means within said housing positioned below said collimating means and in registration with the outlet tube to lie in the path of the metallic vapor beam, and means for feeding material onto said support means such that the material is movable along said support means across the metallic vapor beam to be coated thereby.

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