

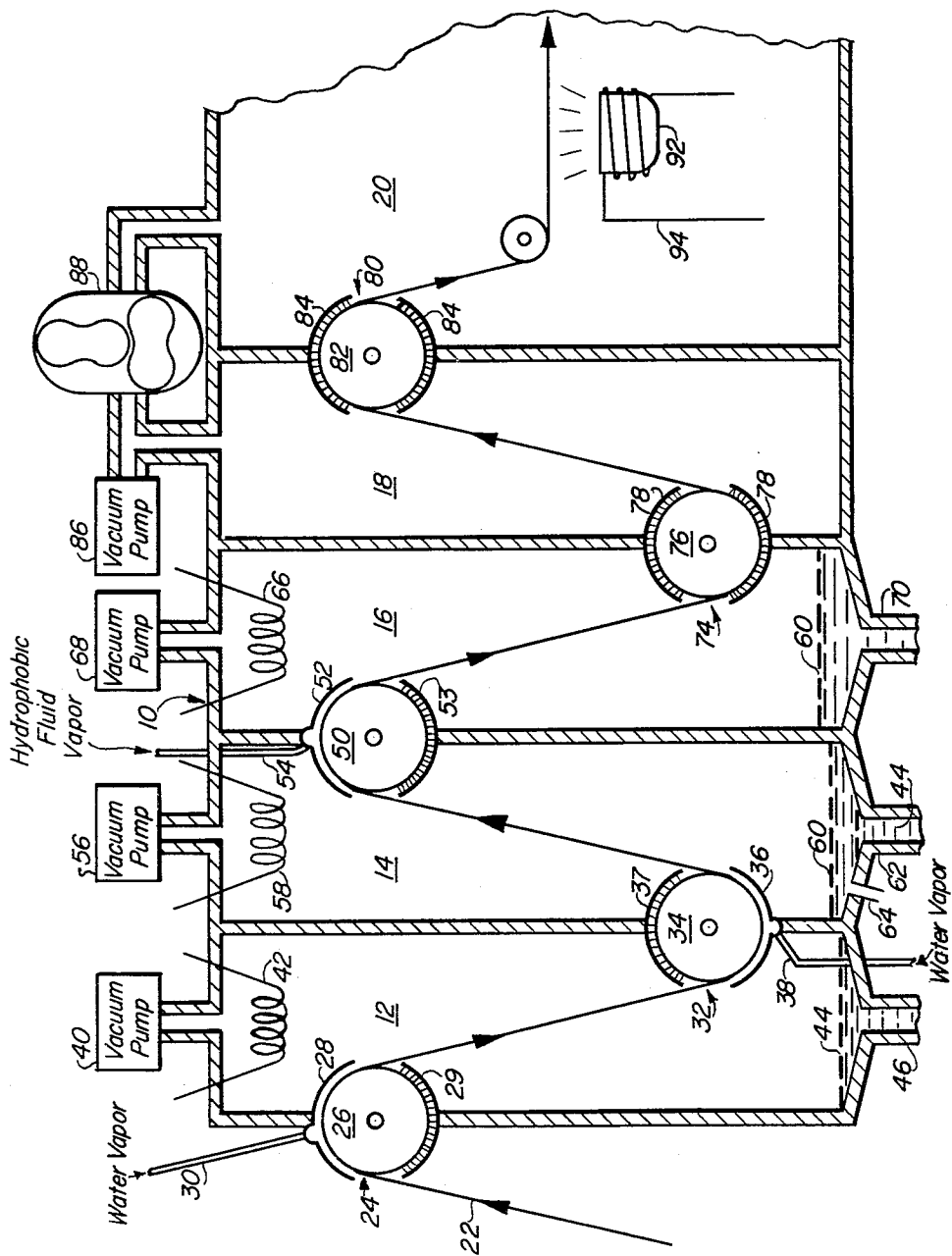
Sept. 19, 1961

M. P. HNILICKA, JR

3,000,346

VACUUM COATING APPARATUS

Filed Nov. 5, 1958



INVENTOR.

BY Milo P. Hnilicka, Jr

Oliver W. Hayes

1

3,000,346

VACUUM COATING APPARATUS

Milo P. Hnilicka, Jr., Concord, Mass., assignor, by mesne assignments, to National Steel Corporation, Pittsburgh, Pa., a corporation of Delaware

Filed Nov. 5, 1958, Ser. No. 772,102

8 Claims. (Cl. 118—49)

The present invention relates to a method and apparatus for the coating of substrates in a vacuum.

A principal object of the present invention is to provide an improved apparatus for the vacuum coating of metallic and non-metallic substrates.

Another object of the invention is to provide an improved method for the vacuum coating of substrates of the above type.

Still another object of the invention is to provide a novel type of vacuum sealing system for apparatus of the above type so that continuous coating operations can be achieved.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the method involving the several steps and the relation and the order of one or more such steps with respect to each of the others and the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing which is a diagrammatic, schematic view of one embodiment of the invention.

The present invention is directed to vacuum coating, and particularly to a vacuum sealing system for introducing and withdrawing a substrate from a vacuum coating operation. For simplicity, the invention will be initially described in connection with its use for the aluminizing of black iron strip.

The vacuum seal and vacuum coating device comprises a first chamber in communication with the atmosphere by means of at least one restricted passage, means for introducing and maintaining in the passage an atmosphere consisting predominantly of a condensible vapor, and means for maintaining the first chamber at a pressure lower than atmospheric pressure. A second chamber is in communication with the first chamber by means of at least one restricted passage which is provided with means for introducing and maintaining therein an atmosphere consisting predominantly of a condensible vapor. Means are also provided for maintaining the second chamber at a lower pressure than the first chamber. A third chamber is in communication with the second chamber by means of at least one restricted passage which is also provided with means for introducing and maintaining therein an atmosphere consisting predominantly of a condensible vapor. The third chamber is provided with means for maintaining it at a lower pressure than the second chamber. A fourth chamber is in communication with the third chamber by means of at least one restricted passage and is provided with means for maintaining it at a lower pressure than the third chamber. This latter chamber, or a chamber following thereafter, contains a source of coating vapors. In other words, the fourth chamber can be the coating chamber, or the coating chamber can be removed from the third chamber by interposing therebetween one or more additional chambers, each succeeding chamber being preferably maintained at a lower pressure than the preceding chamber. Means are

2

also provided for passing a substrate through the passages and chambers.

In one embodiment of the invention, means are provided for introducing into the passage between the first chamber and the atmosphere a condensible vapor at a pressure above atmospheric. In a preferred embodiment of the invention, the condensible vapor is water vapor and a steep pressure gradient is maintained between the chambers by condensing the majority of the mass of condensible vapor flowing into each chamber.

By introducing and maintaining an atmosphere of a condensible vapor within the passage connecting the atmosphere with the first chamber of the vacuum system, the differences in pressure therebetween can be selected so that there is no tendency for air to leak into the system. For instance, by introducing into the above-mentioned passage a condensible vapor at a pressure which is slightly higher than that of the atmosphere, the condensible vapors must flow from the region of higher pressure to that of lower pressure. The condensible vapors, therefore, flow from the point of introduction both into the vacuum chamber and also through the passage out into the atmosphere, thus preventing air from entering the vacuum system. Most of the vapors which enter the first vacuum chamber are condensed and removed as liquid of very small volume.

Thus, the passages carrying the substrate into and out of the chamber in communication with the atmosphere can be made sufficiently large so as to permit the free movement of the substrate therethrough. By preventing air from entering the vacuum system, the pumping systems are not overtaxed and less expensive pumping systems of smaller capacity can be employed. The introduction of a condensible vapor into the passages between the first few chambers of the vacuum system and the condensing of the condensible vapors within the chambers maintains the desired low pressures in the various chambers with the use of economical pumping means. Upon condensation of the condensible vapor, the removal of a liquid from the system is more economical than the pumping of the equivalent mass of material in gas form. Since the condensible vapor is introduced into the substrate passages connecting the chambers, a very efficient and effective seal is achieved between chambers with a minimum input of condensible vapor.

Although the kinetic energy of condensible vapors flowing outwardly from the first passage into the atmosphere substantially sweeps from the substrate surface the air adhering thereto, some non-condensable air does enter the vacuum system on the surface of the rapidly moving substrate. However, by utilizing a plurality of substrate passages in which there is introduced condensible vapors the partial pressure of non-condensibles within the vacuum system is greatly reduced.

For convenience of illustration, the invention will be described in connection with the use of water vapor as the condensible vapor, without intent to limit the invention.

Referring now to the drawing, 10 represents a vacuum coating device comprising a plurality of chambers or compartments 12, 14, 16 and 18 and a coating chamber 20. Fewer or more chambers preceding coating chamber 20 than illustrated can be employed, if desired. Although only the introduction of the substrate 22 into the vacuum coating system is shown, it is obvious that the substrate after coating can be withdrawn therefrom by passing it through a series of chambers after coating chamber 20 or by passing it back through some or all of the chambers employed in its introduction.

Chamber 12 is in communication with the atmosphere by means of a passage 24 which is shown here as being defined by roller 26 and housing member 28 suitably

spaced therefrom. Water vapor supplied from a suitable source, not shown, is directly introduced by means of conduit 30 into about the center of passage 24. The bottom of roller 26 is sealed to housing member 29 by a conventional seal.

Chamber 14 is in communication with chamber 12 by means of a passage 32 shown as being defined by roller 34 and housing members 36 and 37 suitably spaced therefrom. Water vapor is supplied through the housing member 36 into passage 32 by means of conduit 38 which is connected to a suitable supply of water vapor. Chamber 12 is maintained at a reduced pressure by condensing the majority of the water vapor flowing into chamber 12 from passages 24 and 32 and by removing non-condensibles by means of a small pumping system 40. The condensation of the water vapor is achieved by condensing means 42 shown here as coils cooled by suitable means. The condensate 44 (water) is removed from chamber 12 through conduit 46 by means of a pump or suitable barometric leg arrangement, not shown.

Chamber 16 is in communication with chamber 14 by means of passage 48 shown here as being defined by roller 50 and housing member 52 suitably spaced therefrom. Housing member 53 seals the bottom of roller 50. Condensable vapor from a suitable source (not shown) is supplied through the housing member 52 into passage 48 by means of conduit 54. As shown here, instead of water vapor, there is introduced through conduit 54 a condensible hydrophobic fluid vapor such as a halogenated hydrocarbon, oil or silicone. Obviously, passages 24, 32 and 48 can all be supplied with just water vapor, or they can be supplied with just a condensible hydrophobic fluid vapor. Equally some of the passages can be supplied with water vapor and others with a condensible hydrophobic fluid vapor. When the latter embodiment is employed (which is shown in the drawing), then it is preferred that the fluid employed be one which, in the liquid state, is immiscible with water.

Chamber 14 is maintained at a reduced pressure by condensing the majority of condensible vapors (water and hydrophobic fluid) flowing into chamber 14 from passages 32 and 48 and by removing non-condensibles by means of a small pumping system 56. The condensation of the condensible vapors is achieved by condensing means 58 shown here as coils cooled by suitable means. The condensates, water 44 and the hydrophobic fluid 60 are removed from chamber 14 in liquid form through conduits 62 and 64, respectively. The fluid 60 after recovery can again be vaporized and recycled for further use. Whether or not the hydrophobic fluid employed separates readily as a layer 60 over the water 44 as shown, of course, depends upon the ratio of the specific gravities of the fluid and water and upon its hydrophobic properties. If an emulsion is formed, a centrifuging or coagulation may be needed for recovery.

Chamber 16 is maintained at a reduced pressure by employing condensing means 66 to condense the majority of condensible vapors flowing into chamber 16 from passage 48 and by removing non-condensibles by means of a small pumping system 68. The condensate, which in this case would be primarily hydrophobic fluid 60 with little or no water, is removed from chamber 16 through conduit 70.

Chamber 18 is in communication with chamber 16 by means of restricted passage 74 defined by roller 76 and housing members 78. Chamber 20 is in communication with chamber 18 by means of restricted passage 80 defined by roller 82 and housing members 84. The passages 74 and 84 can be sealed by conventional means. Chambers 18 and 20 are evacuated by means of suitable pumping systems wherein 86 illustrates a rotary vacuum pump and 88 is a high vacuum blower. Pumping systems other than those illustrated can also be employed.

Within coating chamber 20 is a source 92 (illustrated here as a crucible means) for holding the metal, such as

aluminum, to be melted and evaporated. When the substrate 22 is to be coated on both sides an additional source, not shown, is employed. The source 92 is suitably heated by means 94 illustrated as induction heating means. Other types of sources and heating means can also be satisfactorily employed.

The operation of the apparatus will be initially described in connection with the coating of sheet steel with aluminum. A suitable sheet of steel is aligned in the manner indicated in the drawing. The crucible 92 is charged with aluminum to be evaporated. The chambers 12, 14, 16, 18 and 20 are evacuated by means of their respective pumping systems so that a proper pressure gradient is established.

Water vapor (steam) is introduced through conduits 30 and 38 so as to flow into and through passages 24 and 32, respectively. The water vapor introduced into passage 24 is preferably at a pressure which is slightly higher than that of the atmosphere so that some of the water vapor must flow outwardly through passage 24, thus preventing air from leaking into the system. A condensible hydrophobic vapor is introduced through conduit 54 so as to flow into and through passage 48.

Chamber 12 is maintained at a pressure lower than the atmosphere by condensing means 42 and pumping system 40. The water vapor flowing into chamber 12 from passages 24 and 32 is condensed by condensing means 42. The conversion of steam to water by means of cooling water at, for example, 20° C. reduces the partial pressure of water vapor within chamber 12 to about 17.5 mm. Hg abs. without the use of other pumping means. Since almost all the mass of gas in chamber 14 is water vapor, only a very small mechanical pump 40 is necessary to remove the noncondensibles and maintain the total pressure in chamber 14 near 17.5 mm. Hg abs. The water 44 is removed from chamber 12 through conduit 46.

Chamber 14 is maintained at a pressure lower than the pressure in chamber 12. This is achieved by employing a suitable pumping system 56 to remove non-condensibles in combination with condensing means 58 which is preferably maintained at a temperature on the order of 1° C. so as to give a low partial pressure of vapor (water and hydrophobic fluid) in chamber 14. The water vapor and hydrophobic fluid vapor flowing into chamber 14 from passages 32 and 48, respectively, are condensed by condensing means 58. The resultant condensates 44 and 60 are removed from chambers 14 through conduits 62 and 64, respectively.

Chamber 16 is maintained at a lower pressure than chamber 14 by employing a suitable pumping system 68 for removing non-condensibles in combination with condensing means 66. Condensing means 66 is preferably maintained at a temperature on the order of -60° C. so as to give a low partial pressure of vapors in chamber 16. The resultant condensate is substantially all hydrophobic fluid since little or no water vapor will pass through passage 48. The condensate 60 is removed from chamber 16 through drain 70.

The aluminum vapor source is heated to melt and evaporate the aluminum charged therein. When the desired evaporation temperature (e.g. 1100° C.) and pressure within chamber 20 (e.g. 0.001 mm. Hg abs.) has been attained, then the substrate 22 is continuously advanced in the manner indicated.

The condensible vapor employed must be inert to the substrate to be coated. That is, it must not affect the substrate either chemically or physically. Water vapor is the preferred vapor, although many materials such as halogenated hydrocarbons, mixed halogenated hydrocarbons (Freons), silicones and the like can also be employed. When water vapor and another fluid vapor are employed in the vacuum system, then the other fluid should be hydrophobic or immiscible with water.

Obviously, many changes can be made in the described apparatus. For example, other types of condensing

5

means than those shown can be employed. Likewise, instead of using a roller with its associated housing members for the passage of the substrate through the various chambers, it is also possible to employ (in combination with a condensible vapor feed thereto) a narrow, elongated linear passage with suitable means for moving the substrate therethrough.

Since certain changes can be made in the above method and apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An apparatus for coating a substrate in a vacuum coating system which comprises a first chamber in communication with the atmosphere by means of at least one restricted passage, means for introducing into said passage an atmosphere of a condensible vapor so that said condensible vapors pass in both directions through said passage, means for maintaining said first chamber at a pressure lower than atmospheric pressure, a second chamber in communication with said first chamber by means of a second restricted passage, means for introducing into said second passage an atmosphere of a condensible vapor so that said condensible vapor passes in both directions through said second passage, means including vapor condensing means, for maintaining said second chamber at a lower pressure than said first chamber, a third chamber in communication with said second chamber by means of a third restricted passage, means, including vapor condensing means, for maintaining said third chamber at a lower pressure than said second chamber, means for passing said substrate through said passages and chambers, and means for vaporizing a coating material so as to deposit a coating on said substrate.

2. Apparatus of claim 1 wherein there is provided means for introducing a condensible vapor at a pressure above atmospheric into the first restricted passage.

3. Apparatus of claim 1 wherein there is provided means for heating the substrate above the condensation temperature of the condensible vapor prior to coating the substrate.

4. Apparatus of claim 1 wherein the restricted passages between the chambers comprises a roller with contour forming housing members spaced therefrom.

5. An apparatus for coating a substrate in a vacuum coating system which comprises a first chamber in communication with the atmosphere by means of a first restricted passage, means for introducing into said passage an atmosphere of a condensible vapor, means for maintaining said first chamber at a pressure lower than atmospheric pressure, a second chamber in communication with said first chamber by means of a second restricted passage, means for introducing into said second passage an atmosphere of a condensible vapor, means, including

6

vapor condensing means, for maintaining said second chamber at a lower pressure than said first chamber, a third chamber in communication with said second chamber by means of a third restricted passage, means for introducing into the third passage an atmosphere of a condensible vapor, means, including vapor condensing means, for maintaining said third chamber at a lower pressure than said second chamber, a fourth chamber in communication with said third chamber by means of a fourth restricted passage, means for maintaining said fourth chamber at a lower pressure than said third chamber, means for passing said substrate through the passages and chambers, and means for vaporizing a coating material so as to deposit a coating on said substrate.

6. An apparatus for coating a substrate in a vacuum coating system which comprises a first chamber in communication with the atmosphere by means of at least one restricted passage, means for introducing into said passage an atmosphere of a condensible vapor so that the condensible vapor flows in both directions in said passage, means for condensing the majority of the mass of condensible vapors flowing into said first chamber to maintain a reduced pressure therein, a second chamber in communication with said first chamber by means of a second restricted passage, means for introducing into said second passage an atmosphere of a condensible vapor, means for condensing the majority of the mass of condensible vapors flowing into said second chamber to maintain said second chamber at a lower pressure than said first chamber, a third chamber in communication with said second chamber by means of a third restricted passage, means for condensing the majority of the condensible vapor flowing into said third chamber to maintain said third chamber at a lower pressure than said second chamber, means for passing said substrate through the passages and chambers, and means for vaporizing a coating material so as to deposit a coating on said substrate.

7. Apparatus of claim 6 wherein there is provided means for introducing an atmosphere of a condensible vapor into the third passage, a fourth chamber in communication with said third chamber by means of a fourth restricted passage, and means for maintaining said fourth chamber at a lower pressure than said third chamber.

8. Apparatus of claim 6 wherein there is provided means for removing the condensed vapors from the chambers.

References Cited in the file of this patent

UNITED STATES PATENTS

981,498	Thomas	Jan. 10, 1911
1,893,716	Ronzzone	Jan. 10, 1933
2,239,770	Becker et al.	Apr. 29, 1941
2,384,500	Stoll	Sept. 11, 1945
2,656,284	Toulmin	Oct. 20, 1953
2,695,743	Williams	Nov. 30, 1954
2,889,674	Hamilton	June 9, 1959