May 31, 1966 T. K. CAULEY ETAL 3,253,945

METHOD AND APPARATUS FOR COATING STRIP MATERIAL BY VAPOR DEPOSITION

Filed Dec. 19, 1963

FIG. 1.

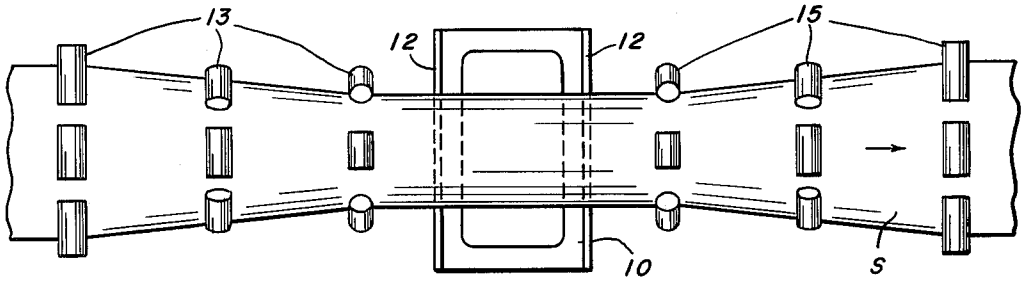


FIG. 2.

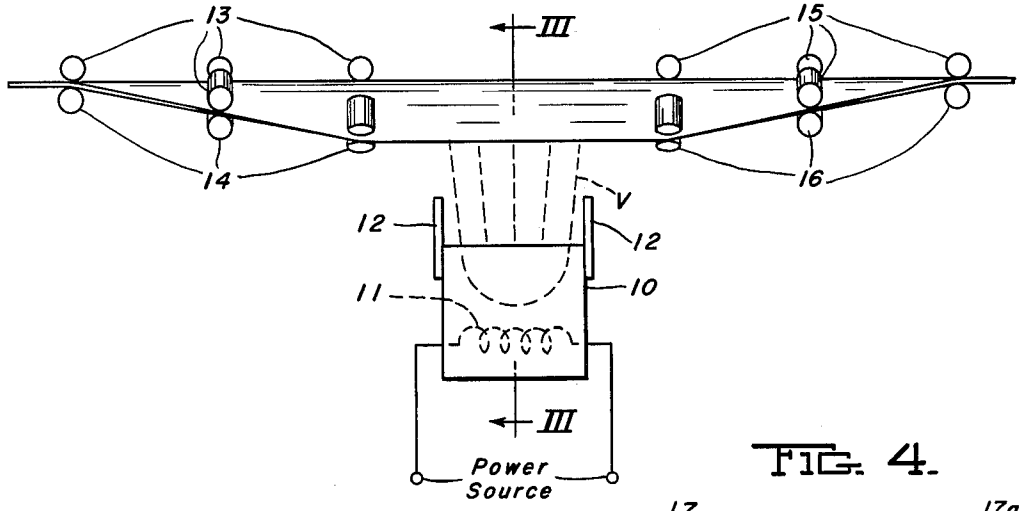


FIG. 3.

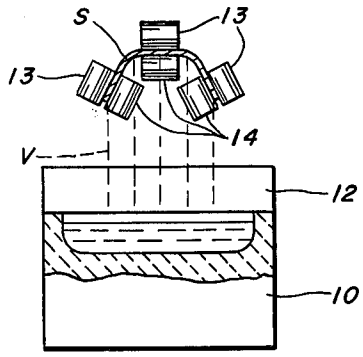
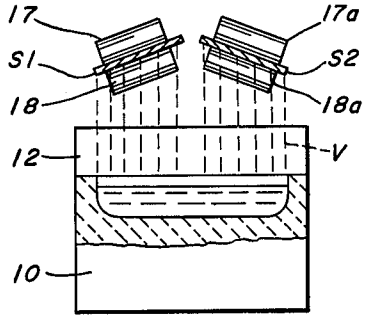


FIG. 4.



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METHOD AND APPARATUS FOR COATING STRIP MATERIAL BY VAPOR DEPOSITION

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7 Claims. (Cl. 117—106)

This invention relates to an improved method and apparatus for coating strip material by vapor-deposition, and more particularly to controlling the thickness and profile of the coating.

In a conventional vapor-deposition process for coating strip material, the strip passes over a crucible which is housed in a vacuum chamber. The crucible contains coating material, which is heated to a sufficient temperature to vaporize it. The vapors condense on the strip surface and form a continuous coating thereon. Such processes can be used, for example, to coat steel strip with aluminum. One problem encountered in these processes is in controlling the coating thickness, particularly in depositing a coating of uniform thickness across the width of a strip. The portion of the strip which passes over the central portion of the crucible tends to acquire a thicker coating than the portions which pass over each side edge.

An object of our invention is to provide an improved method and apparatus for coating a strip by vapor deposition in which we closely control the coating thickness.

A further object is to provide a method and apparatus of the foregoing type in which the undersurface of the strip lies approximately on a band where the vapor density is uniform; as it passes over the crucible; that is, the strip is closer to the crucible at each side thereof than at the central portion.

In the drawing:

FIGURE 1 is a diagrammatic top plan view of a portion of a vapor-deposition coating apparatus equipped with one form of our device for controlling the coating thickness;

FIGURE 2 is a diagrammatic side-elevational view of the apparatus shown in FIGURE 1;

FIGURE 3 is a vertical section on line III—III of FIGURE 1; and

FIGURE 4 is a section similar to FIGURE 3, but showing a modification.

The drawing shows an open-topped crucible **10** which forms part of a conventional coating apparatus. The crucible is equipped with heating means, such as electrical resistance coils **11**, and it contains a supply of coating material which vaporizes on heating. The crucible is housed within a vacuum chamber, not shown. A strip S passes continuously over the crucible, whereby vapors V from the material in the crucible condense on the strip surface and form a coating thereon. The front and back edges of the crucible carry upstanding baffles **12**, which keep the angle of incidence between the vapors and the strip surface closer to 90°, thereby improving the quality of coating. The foregoing apparatus is well-known and hence is not shown in further detail. Nevertheless reference can be made to McManus et al. Patent No. 2,382,432 or Stoll Patent No. 2,384,500 for more complete showings of apparatus of this type.

In accordance with the embodiment of our invention shown in FIGURES 1, 2 and 3, we mount series of opposed upper and lower shaping rolls **13** and **14** ahead of crucible **10** and other series of opposed upper and lower shaping rolls **15** and **16** following the crucible. As the strip approaches the crucible, it passes between rolls **13** and **14** which bend it to a downwardly concave arc best shown in FIGURE 3. As it leaves the crucible,

it passes between rolls **15** and **16** which restore it to a flat configuration. The number and arrangement of shaping rolls of course varies with the type of strip and the extent to which it is to be bent. We show three series of rolls on the entry side and three on the exit side, with three rolls in each series. In each instance the middle roll is journaled on a horizontal axis and the outer rolls on inclined axes. The angle of inclination becomes greater the closer to the crucible, whereby the strip bends and flattens gradually. We can use either idler or power driven rolls.

FIGURE 4 shows a modification in which individual strips S_1 and S_2 pass over the same crucible. Upper and lower shaping rolls **17** and **18** position strip S_1 so that it slopes downwardly from a line above the central portion of the crucible toward the left. In like fashion upper and lower shaping rolls **17***a* and **18***a* position strip S_2 so that it slopes downwardly toward the right. One of the strips S_1 or S_2 of course may be the return pass of the other after the strip has been inverted.

The density of the vapors V of coating material of course becomes lower the greater the distance above the crucible. At any given distance the vapors have their greatest density above the central portion of the crucible. As FIGURES 3 and 4 show, the undersurface of the strip lies closer to the supply of coating material in the crucible at the edges of the crucible than at the central portion. To deposit a coating of uniform thickness, we position the strip so that its full width lies approximately on a band where the vapors are of the same density. By positioning the strip in other ways, we can also deposit coatings whose thickness varies according to predetermined patterns. Another benefit which results from our invention is that the strip acts to confine the vapors adjacent the edges of the crucible. Since the strip lies closer to the crucible at the edges, less vapor can escape.

While we have shown and described certain preferred embodiments of our invention, it is apparent other modifications may arise. Therefore, we do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

We claim:

1. In a process for coating strip material in which a continuous strip passes over a supply of coating material, the coating material is heated to vaporize it, and the vapors condense on the strip surface to form a coating thereon, the density of the vapors being greatest near the central portion of the supply at any given distance thereabove, a method of controlling the thickness of coating deposited on the strip comprising positioning the strip as it approaches the supply so that it is closer to the supply at the edges thereof than at the central portion, whereby the undersurface of the strip lies approximately on a band where the vapor density is uniform across its width as the strip passes over the supply.

2. A method as defined in claim **1** in which the strip is bent to a downwardly concave arc as it approaches the supply and restored to flatness after it passes.

3. A method as defined in claim **1** in which separate strips pass over said supply, each of which strips slopes downwardly from a line above the central portion of the supply toward opposite edges thereof.

4. In an apparatus for coating strip material, which apparatus includes a crucible adapted to contain a supply of coating material, means for heating the crucible to vaporize the coating material, and means for moving a continuous strip over the crucible to enable the vapors to condense on the strip surface and form a coating thereon, the density of the vapors being greatest near the central portion of the crucible at any given distance thereabove, the combination therewith of a device for controlling the thickness of coating deposited on the strip, said device comprising means mounted ahead of said crucible and engaging

the strip to position it so that it is closer to the crucible above the edges of the crucible than at the central portion, whereby the undersurface of the strip lies approximately on a band where the vapor density is uniform across its width as the strip passes over the crucible.

5. A combination as defined in claim 4 including means for bending the strip to a downwardly concave arc as it approaches said crucible and means for restoring the strip to flatness after it passes the crucible.

6. A combination as defined in claim 5 in which the means for bending and restoring the strip include a series of upper and lower shaping rolls between which the strip passes, the outer rolls of each series being journaled on axes inclined to the horizontal, the angle of inclination becoming greater the closer to the crucible.

7. A combination as defined in claim 4 including means for guiding individual strips across the same crucible and positioning said strips so that each slopes downwardly from a line above the central portion of the crucible toward the edges.

No references cited.

RICHARD D. NEVIUS, *Primary Examiner.*

Disclaimer

3,253,945.—*Thomas K. Cauley*, West Mifflin Boro, Pa., and *James I. Maher*, La Verne, Calif. METHOD AND APPARATUS FOR COATING STRIP MATERIAL BY VAPOR DEPOSITION. Patent dated May 31, 1966. Disclaimer filed July 13, 1966, by the assignee, *United States Steel Corporation.*

Hereby enters this disclaimer to claims 1 and 4 of said patent.

[*Official Gazette October 11, 1966.*]