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GENERATION OF LIQUID-FREE METAL VAPOR

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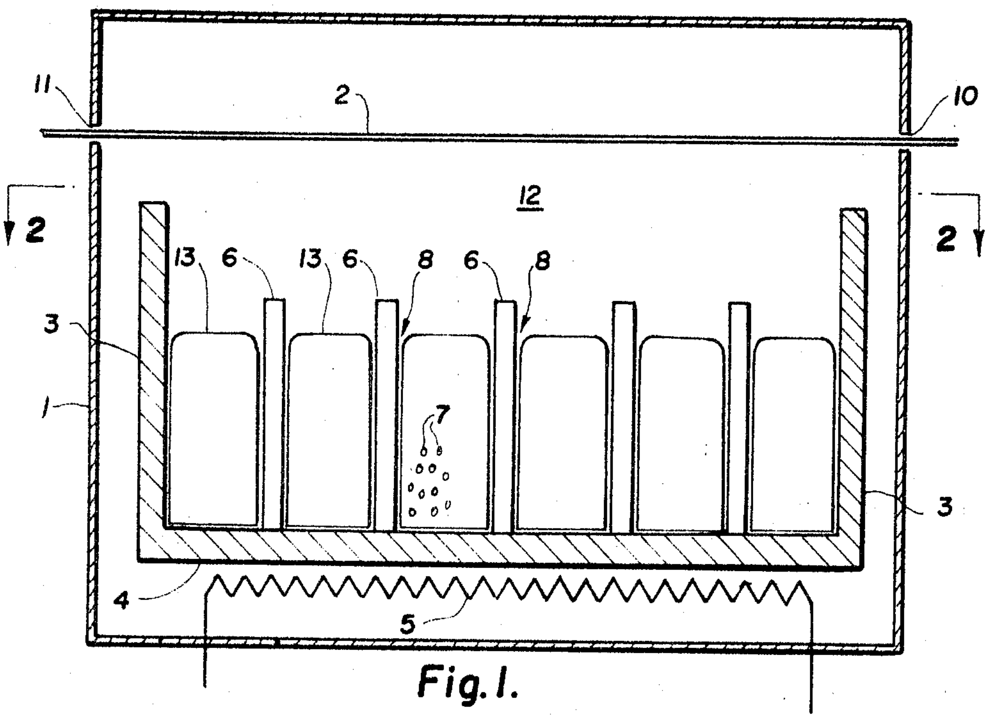


Fig. 1.

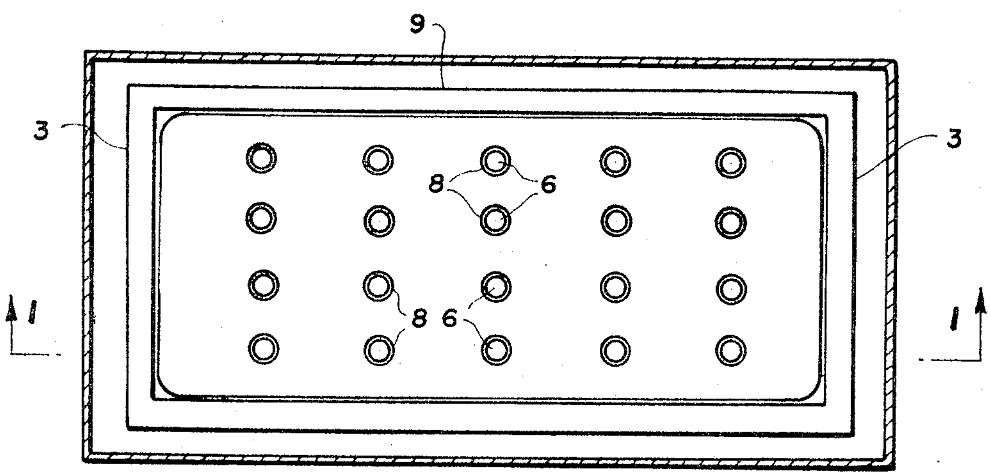


Fig. 2.

INVENTORS
JOSEPH P. GIMIGLIANO
JOHN F. BUTLER
BY
ATTORNEY

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# GENERATION OF LIQUID-FREE METAL VAPOR

Joseph P. Gimigliano, O'Hara Township, Allegheny County, and John Francis Butler, Bethel Park, Pa., assignors to Jones & Laughlin Steel Corporation, Pittsburgh, Pa., a corporation of Pennsylvania

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## ABSTRACT OF THE DISCLOSURE

The method of the invention comprises the spatter-free evaporation of a coating metal by heating it in a crucible having upstanding heat conducting projections of a material not wetted by the coating metal extending from its bottom to the molten metal surface.

This invention is concerned with the surface coating of a substrate by condensation thereon of a metal vapor in a vacuum. It is more particularly concerned with a method of generating a vapor of a coating metal substantially free from entrained particles of liquid coating metal.

It is known that in the evaporation of various nonferrous metals used as coating metals, liquid particles become entrained in the vapor as liquids or solids when boiling of the liquid occurs. This undesirable situation is described in Chen et al., U.S. Patent No. 2,793,609 of May 28, 1957, and the deleterious effects of such spattering on the vapor deposited coating are there pointed out. That patent discloses apparatus employing baffles to arrest particles thrown off from the surface of the coating metal and prevent the from reaching the surface of the substrate being coated, but does not disclose any way of eliminating the generation of such undesired particles. It is not necessary to distinguish between liquid particles and solidified particles with respect to our invention to be described, and we include both under the description of "liquid particles" hereinafter.

It is an object of our invention to provide a process of evaporating coating metals at a high rate which does not throw off liquid particles or allow them to become entrained in the vapor. It is another object to provide a process of boiling a coating metal so as to convert it into vapor without at the same time tthrowing out particles of liquid.

We have found that the undesirable throw-off of liquid particles and their entrainment in the vapor normally occurs when liquid coating metal is caused to boil is a result of the bursting at the liquid surface of bubbles of metallic vapor generated principally at the bottom of the liquid metal. We have also found that generation of such bubbles at the bottom of the liquid can be suppressed or the bursting of these bubbles at the liquid surface can be prevented if other avenues of escape are provided for the vapor generated at the bottom of the liquid metal. We provide such avenues by positioning within the pool of liquid coating metal projections which extend from the bottom of the crucible to a level at or above the surface of the liquid metal. These projections are made of a material which conducts heat but which is not wetted by the molten metal.

Our invention will be more readily understood by references to the attached drawings of an embodiment of our invention presently preferred by us. FIGURE 1 is a vertical cross-section, partly schematic, of apparatus adapted to practice our invention, taken on the plane 1—1 of FIGURE 2. FIGURE 2 is a horizontal section taken on the plane 2—2 of FIGURE 1.



An evacuated chamber **1** is provided with entrance and exit openings **10** and **11** respectively, through which substrate **2** in the form of flat strip is continuously passed. Beneath substrate **2** is positioned crucible **12** comprising side walls **9—9**, end walls **3—3** and bottom **4**. Beneath bottom **4** is an electrical resistance heating element **5**.

From the bottom **4** of crucible **12** a plurality of upright cylindrical projections **6—6** extend to a level somewhat above the upper surface **13** of the molten coating metal contained in crucible **12**. Projections **6—6** are made of a material which is not wetted by the molten coating metal and which conducts heat.

While we do not wish to commit ourselves to any specific theory of operation of our process, we presently believe that it is effective because it facilitates the evaporation of metal at or near the surface of the molten pool and either suppresses the formation of vapor bubbles at the bottom of the molten metal or provides a way of escape for metallic vapor generated therein. In the absence of projection **6—6**, we believe that bubbles of metal vapor indicated at **7—7** in FIGURE 1 would nucleate on the bottom **4** of the crucible as it receives heat from element **5**. These bubbles would rise to the surface, and the greater the temperature gradient between the bottom and upper surface of the molten metal, the greater the vapor pressure resulting in the formation of bubbles. The bubbles expand as they rise and burst at the metal surface, allowing the vapor to escape and throwing off particles of metal from the metal film above the bubble immediately before it bursts or from the liquid jet produced by the molten metal filling the cavity left by the escaping bubble.

The heat conducting projections **6—6**, however, provide heated surfaces near the upper surface of the molten metal for vapor generation. As the metal does not wet projections **6—6** there is a thin annular gap or space around each projection **6** through which vapor so generated can escape. Those spaces are indicated at **8—8** in FIGURE 2. Consequently, vapor generated at the projections **6—6** is substantially free from entrained particles of liquid. Vapor pockets formed on the bottom **4** have a considerable probability of coming into contact with the surfaces of projections **6—6** on the bath bottom before these pockets can detach themselves from the bottom and form bubbles. The vapor generated at the bottom therefore escapes through the spaces **8—8** in the way described, as though it had originally formed on projections **6—6**.

For the reasons made clear, it is desirable that the walls of the crucible used in our process be of the same characteristics as those specified herein for the projections **6—6**. The tops of those projections may be flush with the metal surface or project above it. If, however, the projections terminate short of the metal surface, vapor escaping along the surfaces of the projections will reach the surface as bubbles, the bursting of which tends to throw out liquid metal. While cylindrical projections are the simplest form to employ, those of other sections are also satisfactory. In general, the more numerous these projections and the closer together they are spaced, the more effective they are to suppress liquid throw-out and entrainment.

An installation of our invention with which we are familiar makes use of upstanding cylindrical projections of graphite ⅜" in diameter, spaced over the crucible bottom so that those nearest each other are about 1½" apart. In the absence of such projections, molten zinc can be heated in this crucible to evaporate metallic zinc without splattering at the rate of 20 to 30 pounds per square foot of crucible surface per hour. With the projections above described, spaced in the manner above described, the same crucible evaporates zinc without splattering at the rate of about 80 pounds per square foot of crucible surface per hour.

We claim:

**1.** In the vacuum vapor coating of a substrate with a vaporized metal, the method of evaporating the coating metal so as to minimize entrainment of liquid in the metal vapor comprising heating a pool of molten coating metal in contact with a plurality of upstanding projections extending from the bottom to the upper surface of the pool, the projections being of a material which conducts heat but which is not wetted by the molten coating metal, and continuing the heating to bring about vaporization of the coating metal below the surfaces of the pool and escape of that vapor along the surfaces of the projections.

**2.** The method of claim **1** in which the material for the projections is graphite.



**3.** The method of claim **1** in which the projections are spaced through the pool so as to provide for the escape therealong of substantially all the vapor generated at the bottom of the pool.

**4.** The method of claim **2** in which the coating metal is zinc.

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ALFRED L. LEAVITT, Primary Examiner

A. GOLIAN, Assistant Examiner

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