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METHOD AND APPARATUS FOR THE FORMATION OF HOT DIP COATINGS

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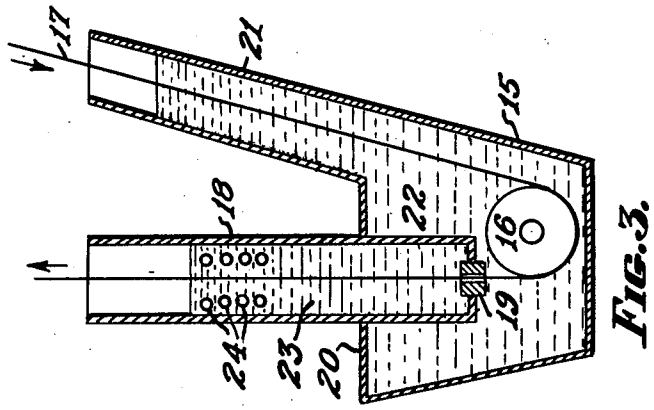



FIG. 3.

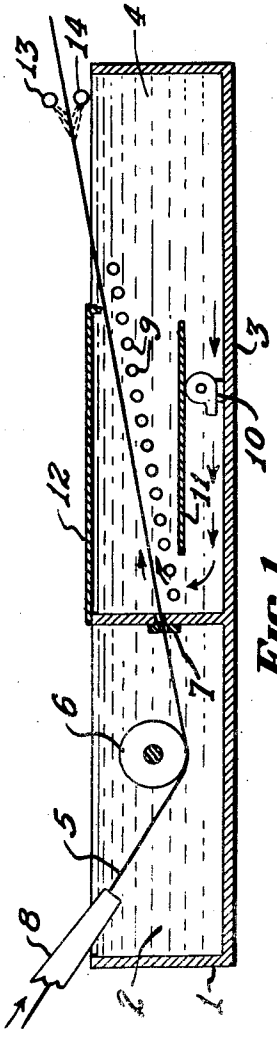



FIG. 1.

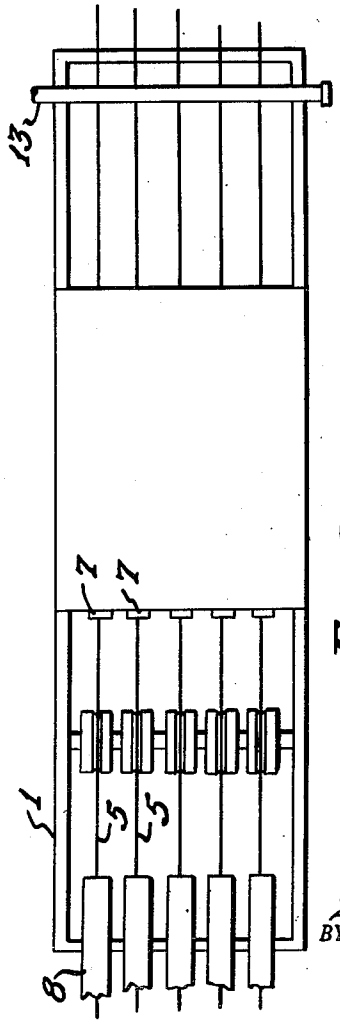



FIG. 2.

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## METHOD AND APPARATUS FOR THE FORMATION OF HOT DIP COATINGS

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Our invention has to do with the coating of metal articles with molten dissimilar materials, and relates particularly to the coating of metal articles in strand form, i. e., wire, irrespective of its diameter, and strip, irrespective of its width. The nature of the metal making up the metal articles forms no limitation on the invention. It is only necessary that the metal or alloy be one capable of being formed into the desired strand type articles, one capable of withstanding the heat of the molten coating metal bath, and one having at least a surface capable of bonding with the molten coating metal. The nature of the molten coating metal likewise does not form a limitation on the invention; and the process and apparatus hereinafter described are applicable to the coating of metal articles with any of the molten coating metals employed in the art for that purpose, inclusive of zinc, zinc alloys, aluminum, aluminum alloys, magnesium, magnesium alloys, lead, tin and terne.

A principal object of our invention has to do with the provision of apparatus and a process for forming uniform and controlled hot dipped coatings on metal articles.

Another principal object of our invention has to do with the formation of heavy controlled coatings of thicknesses greater than those hitherto capable of being controlled as to thickness and uniformity.

In the manufacture of coated metal products, the metal strand is passed through a bath of molten coating metal and carries a layer of this metal with it as it emerges from the bath. The coating so carried remains molten on the surface of the metal article for some time and distance after the article leaves the bath surface. There are various ways in which some control can be exercised over the mean weight of coating carried by the metal article out of the bath; but inequalities in the thickness of the coating are likely to occur through various conditions at the bath surface and through the influence of gravity and possibly momentum above the bath surface while the molten coating metal is still soft. Differences in uniformity are encountered even with thin coatings; but they increase generally with coating thickness.

It is often desirable to coat the metal articles, e. g. iron or steel articles with heavy or thick coatings to attain exceptional corrosion or wear resistance, or in the case of wire, to provide improved electrical conductivity. It has been proposed in the case of wire coated with zinc to withdraw the wire from the bath vertically,

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using no wipers and water-chilling the coating quickly to keep it in place on the wire. Attempts have been made to withdraw both wire and strip at an angle from the bath. In some cases for the production of heavy coatings, it has been suggested to blow the molten metal up out of the bath and onto an inclined strip. One of the most serious problems in the production of heavy coatings, particularly on wire, is the need of prompt quenching to maintain the ductility of the coating and to prevent it from running back into the bath. While the metal is in a liquid or plastic state, it is difficult to cool it artificially without producing roughening; and in most instances the coating either is applied in a non-uniform way or becomes non-uniform immediately upon its emergence from the bath. Light and heavy striations in the coating on strip, and knots or beads of the coating metal, commonly called "berries" on wire, are familiar to the skilled worker in the art.

Objects of our invention are the solution of the problems set forth above.

Another object of our invention is the provision of apparatus and a method in which the coating applied to the wire or strip can initially be sized or carefully controlled as to thickness, in which the coating can be supported while molten or plastic in such a way as to prevent non-uniformity after the strand has left the bath and until the coating has solidified, and in which the supporting forces acting on the non-solid coating tend to permit the coating to become more uniform in distribution through surface tension effects.

These and other objects of our invention, which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, we accomplish in that procedure and by that construction and arrangement of parts of which we shall now describe an exemplary embodiment. Reference is made to the accompanying drawings wherein:

Figure 1 is a diagrammatic section of an apparatus for coating metal strands in accordance with our invention.

Figure 2 is a diagrammatic plan view of the same apparatus.

Figure 3 is a digrammatic vertical section of a somewhat modified apparatus.

Briefly in the practice of our invention, we withdraw a strand-type article to be coated from a bath of the molten coating metal through a sizing orifice, but immediately upon the emergence of the coated article from the bath, we

pass it into or through a bath of molten material which is not only inert to the coating metal, but has a density close to that of the molten metal, so that it can act as a support for the coating while it is still molten. The coating is cooled and solidified while the coated article is in the second bath and prior to its emergence therefrom.

The effect of the elements just described depends upon their coaction. For example, the effect of a sizing orifice through which the strand is withdrawn cannot be the effect we desire unless the molten coating on the strand is supported immediately beyond the orifice by the inert bath of similar density. Otherwise the molten coating metal will be affected by gravity, and in the case of horizontal withdrawal from the molten coating bath, will either drip off the strand or will collect in droplets or heavier and lighter striations prior to its solidification. In the case of vertical withdrawal, the molten metal will run down the strand, the general thickness of the coating may be diminished, and non-uniformity will result. The formation of the familiar meniscus above the exit rolls in galvanizing operations is a case in point. On the other hand, the use of an inert supporting bath, while it tends to prevent gravitational effects on the coating while molten and also tends to promote uniformity through surface tension effects, cannot produce the utmost uniformity unless the specific quantity of metal carried by the strand out of the bath is accurately determined by a suitable sizing means, and in particular, it cannot produce uniformity if conditions at the surface of the molten metal bath result in non-uniformity of deposit.

It is not necessary that the density or specific gravity of the inert bath be exactly that of the molten coating metal. It should be sufficiently close to it to support the coating while molten to obtain the effects above described. In some instances, as where the strand leaves the bath vertically, it may be found desirable to employ an inert bath having a slightly greater density than that of the molten coating metal in order to float away from the sizing orifice member any metal or other substance tending to accumulate on the exit side thereof.

For a sizing means we prefer to employ means in the nature of a die, made of metallic or non-metallic material of suitable wear resistance and inert both to the molten coating metal and to the inert bath. The opening in the die will be sufficiently greater in area than the cross-sectional area of the wire or strip being treated to provide for the desired weight of coating. We are not, however, limited to the use of fixed orifice members, especially for strip, since it is possible to employ means such as exit rolls with the strip passing between them, which exit rolls are sealed by suitable doctor means or dams to the wall of the coating pot about the exit orifice thereof.

Referring to Figures 1 and 2, we have shown at **1** a coating pot in which a bath **2** of the molten coating metal is maintained. Adjacent this pot, and having a wall common therewith, we have shown a vessel **3** in which the inert bath **4** is maintained. The strand **5**, which in Figures 1 and 2 is illustrated as a wire, passes into and through the bath **2** of molten coating metal and about such guiding sheaves **6** as may be required. It passes from the bath of molten coating metal into the inert bath **4** through an opening in the common wall, which opening is provided with a die or other sizing means **7**.



The pretreatment which the strand may have received is not a limitation on the invention. We have indicated at **8** the end of a hood element from a pretreatment furnace, which end dips beneath the bath of molten coating metal. One suitable pretreatment is that set forth in the Sendzimir Patent No. 2,110,893, dated March 15, 1938, in which the strand is first passed through an oxidizing furnace in which combustible materials are burned from its surface and in which a thin controlled oxide coating is formed. Next it passes into and through a reducing furnace in which a suitable atmosphere reduces the thin oxide coating, in which the strand is softened by annealing, and which is provided with a cooling hood to reduce the temperature of the strand to slightly above bath temperature before it is introduced into the bath. The index numeral **8** indicates the end of this hood. However, other pretreatments including the passage of the strand through fluxes and the like may be employed without departing from the spirit of our invention.

The inert bath **4** in its vessel **3** may be subjected to heating or cooling or both by various means including the circulation of temperature control fluids through heating or cooling coils **9**. If desired, circulation may be maintained in the inert bath **4** and we have illustrated diagrammatically a pump **10** and baffle **11** for this purpose. A partial cover **12** may be provided for the inert bath. A substantial flow of the inert bath in the direction in which the strand is moving is desirable when high coating speeds are used.

It will be understood that prior to the emergence of the strand from the inert bath **4**, the coating of molten metal thereon will have become solidified. Upon the emergence of the strand, it may be desired to clean from its surfaces any carry-out of the material of the inert bath. We have indicated at **13** and **14** steam jet devices which may be employed for this purpose. A temperature gradient is maintained in the inert bath from a temperature at the point where the strand or strands enter it, which will be close to but may be somewhat lower than the temperature of the bath of molten coating metal, to a temperature in remoter portions of the inert bath which will be lower than the solidification temperature of the molten coating metal. The vessels may be so constructed that heat transfer will occur through the common wall and the temperature gradient may be maintained by radiation from other parts of the inert bath. However, it is within the scope of our invention to maintain the desired temperature gradient by means of the heating and cooling coils **9** or equivalent apparatus.

As has already been indicated, the bath **4** should be of a material inert to the molten coating metal and of a density similar to the density of the molten coating metal. It should further be of a material which will be in the liquid phase from a temperature as high as that of the molten coating metal to and below a lower temperature at which the molten coating metal becomes solidified. Beyond these requirements, however, the material of the inert bath may be any desired. Ordinarily fused salts having the required liquid range and density are chosen. The choice of materials is not confined to fused salts, however. For example, in the coating of steel wire with aluminum, a material available for the inert

bath is molten sulphur which has a density close to that of molten aluminum. By way of further examples for aluminum coating a fused salt mixture comprising cryolite and alumina in such proportions as to give the required density may be employed, or a bath of aluminum fluoride and barium fluoride in proportions to give a melt approaching the density of molten aluminum very closely. For a zinc coating we may employ among other things a bath composed of zinc chloride and lead oxide or tungsten oxide in proportions to give a density close to or the same as that of molten zinc

In a particular exemplary procedure using apparatus like that illustrated in Figures 1 and 2, a steel wire, approximately .100 in. in diameter, was coated with aluminum in the pot 1 and caused to exit into molten sulphur through an orifice approximately .120 in. in diameter. The coated wire, cooled while supported by the sulphur, was found to carry an exceptionally heavy coating of approximately .060 in. in thickness which was uniform around the circumference of the wire and in the direction of its length.

Our process affords the opportunity of varying the thickness of the coating of molten metal to a useful degree even with a fixed orifice size. Three factors appear to govern the specific thickness of the coating. These factors are the size of the orifice through which the article to be coated is drawn, the hydrostatic head of the coating metal at the orifice, and the speed of travel of the strand-like article. In connection with the hydrostatic head of the molten metal, it will be understood that since the density of the inert bath is substantially the same as that of the molten coating metal, the hydrostatic head may be controlled by varying the respective levels of the two baths. Thus our invention contemplates raising the surface level of the molten metal coating bath above that of the inert bath when a greater thickness of the coating and hence a higher hydrostatic head is desired. Positive pressure at the die or orifice may, however, be otherwise secured, as for example, by covering the coating metal pot and exerting pressure upon the surface of the coating metal, as by a gas. The speed of travel of the strand is a factor in the control of coating thickness but is considered a secondary control factor to be tied in with the other factors of hydrostatic head, orifice size, temperature of the coating bath and the like. For any given set of conditions, increasing the speed of travel of the strand beyond a certain point will not necessarily increase the thickness of the coating. The effect of the orifice size is obvious. The temperature of the coating bath may be used to control to some extent the thickness of the coating as affecting the viscosity of the coating metal at the orifice. In operating as in the exemplary procedure just outlined, we have found it possible to vary the coating thickness from approximately .002 in. to and beyond the .060 in. previously mentioned.

In Figure 3 we have illustrated a modification of our apparatus in which we provide a coating pot 15 with a sheave 16 or the like to change the direction of the strand 17 to be coated. The inert bath in this instance is contained in a stand pipe 18 projecting downwardly into the bath of molten coating metal and closed at its bottom, excepting for the sizing orifice 19, through which the strand passes. The coating pot is provided with a cover or closure 20 and with a stand pipe 21 through which the strand enters the pot. It



will be clear that conditions of hydrostatic head at the die or sizing orifice 19 may be controlled by varying the surface heights of the molten metal bath 22 and the inert bath 23 in the stand pipe elements 18 and 21. Since the lower end of the stand pipe 18 is submerged in the bath 22, there will be sufficient heat transfer to maintain the temperature of the lower part of the bath 23 at a temperature close to that of the bath in spite of some circulation therein, while artificial cooling may be applied to the upper part of the bath 23 through the medium of cooling coils 24. In the use of the apparatus illustrated in Figure 3, it may be desirable to employ as an inert bath a material having a slightly greater density than that of the molten coating metal for the purpose of floating metal, oxide or other materials away from the die or sizing orifice 19.

An advantage of our procedure and apparatus is that forced or rapid cooling may be employed without destroying the uniformity of the applied coating while the sizing orifice and the supporting of the coating by the inert bath coact to provide a uniform coating of molten metal which is thereafter supported by the inert bath until it has solidified.

Modifications may be made in our invention without departing from the spirit of it. Having thus described our invention in certain exemplary embodiments, what we claim as new and desire to secure by Letters Patent is:

1. A process of coating metallic strand-like elements with molten coating metal which comprises passing a strand-like element through a bath of molten coating metal and through a sizing orifice immediately into a bath of molten inert substance having a density substantially the same as that of the molten coating metal, whereby to form on the strand a uniform coating of the molten coating metal and to support said coating in molten condition immediately after formation, and solidifying said coating while so supported.

2. The process of claim 1 in which a temperature gradient is maintained in said bath of inert material to cool the coating of molten coating metal to below its solidification temperature prior to the passage of the coated strand out of the bath of inert material.

3. The process of claim 1 in which the said bath of inert material is subjected to artificial cooling to chill the molten coating metal rapidly.

4. The process of claim 1 in which the molten coating metal is maintained under conditions of positive pressure at the said orifice greater than the reverse pressure exerted by the bath of inert material.

5. The process of claim 3 in which the molten coating metal is maintained under conditions of positive pressure at the said orifice greater than the reverse pressure exerted by the bath of inert material, by maintaining a higher level in said bath of molten coating metal than in said bath of inert material.

6. The process of claim 3 in which the molten coating metal is maintained under conditions of positive pressure at the said orifice greater than the reverse pressure exerted by the bath of inert material, by maintaining a higher level in said bath of molten coating metal than in said bath of inert material, and in which the thickness of the coating of molten metal is further controlled by controlling the speed of passage of the strand through the said orifice.

7. A process of coating metallic strand-like

elements with molten coating metal which comprises passing a strand-like element through a bath of molten coating metal and through a sizing orifice immediately into a bath of molten inert substance of substantially the same density and controlling the thickness of the coating of molten metal deposited upon the said strand by controlling the size of the said orifice, the speed of travel of the strand and the hydrostatic head of said molten coating metal at said orifice.

8. In coating apparatus a metal coating pot for containing a metal coating bath, a vessel containing a bath of inert material of substantially the same density as the metal coating bath immediately adjacent the said metal coating pot and means connecting the pot and vessel and comprising a sizing orifice through which a strand to be coated may be passed from the bath of molten coating metal into and through the bath of inert material.

9. In coating apparatus a metal coating pot for containing a metal coating bath, a vessel containing a bath of inert material of substantially the same density immediately adjacent the metal coating pot and means connecting the pot and vessel and comprising a sizing orifice through which a strand to be coated may be passed from the bath of molten coating metal into and through the bath of inert material, and means for producing in said bath of inert material a temperature gradient ranging from substantially the temperature of the molten coating metal adjacent said orifice to a temperature below the freezing temperature of said coating metal at a point remote from said orifice.

10. The structure claimed in claim 8 in which the vessel containing said bath of inert substance is disposed partially within the pot for molten coating metal.

11. The structure claimed in claim 8 in which the vessel containing said bath of inert substance is disposed partially within the pot for molten coating metal, and extends upwardly therefrom as a standpipe, and in which said pot for the molten coating metal is provided with a cover and an upwardly extending standpipe through which said strand enters said bath, whereby the relative pressures of the baths at said orifice may be controlled by controlling the surface levels of the materials of said baths in said standpipes.

12. The structure claimed in claim 8 in which the vessel containing said bath of inert substance is disposed partially within the pot for molten coating metal, and extends upwardly therefrom as a standpipe, and in which said pot for the molten coating metal is provided with a cover and an upwardly extending standpipe through which said strand enters said bath, whereby the relative pressures of the baths at said orifice may be controlled by controlling the surface levels of the materials of said baths in said standpipes, the said orifice being located in the lower part of said first mentioned standpipe vessel and beneath the surface of said molten coating metal.

13. In apparatus for the purpose described, a pair of adjacent vessels having a common wall, one of said vessels being a pot for molten coating metal, the other of said vessels containing an inert molten bath of substantially the same density, said common wall having a passageway formed therethrough and sizing orifice means in said passageway whereby a strand-like metallic element to be coated may be led through a molten coating bath in said first vessel and directly through said sizing orifice into said bath of inert material in said second vessel.



14. In apparatus for the purpose described, a pair of adjacent vessels having a common wall, one of said vessels being a pot for molten coating metal, the other of said vessels containing an inert molten bath of substantially the same density, said common wall having a passageway formed therethrough and sizing orifice means in said passageway whereby a strand-like metallic element to be coated may be led through a molten coating bath in said first vessel and directly through said sizing orifice into said bath of inert material in said second vessel, and cooling means for said bath of inert material to establish a temperature gradient therein.

15. In apparatus for the purpose described, a pair of adjacent vessels having a common wall, one of said vessels being a pot for molten coating metal, the other of said vessels containing an inert molten bath of substantially the same density, said common wall having a passageway formed therethrough and sizing orifice means in said passageway whereby a strand-like metallic element to be coated may be led through the molten coating bath in said first vessel and directly through said sizing orifice into said bath of inert material in said second vessel, and cooling means for said bath of inert material to establish a temperature gradient therein, and means for producing circulation in said bath of inert material.

16. In apparatus for the purpose described, a pair of adjacent vessels having a common wall, one of said vessels being a pot for molten coating metal, the other of said vessels containing an inert molten bath of substantially the same density, said common wall having a passageway formed therethrough and sizing orifice means in said passageway whereby a strand-like metallic element to be coated may be led through the molten coating bath in said first vessel and directly through said sizing orifice into said bath of inert material in said second vessel, cooling means for said bath of inert material to establish a temperature gradient therein, means for producing circulation in said bath of inert material, and means for cleaning said strand of inert material upon its emergence from the bath thereof.

17. In a process of coating a metal article with a heavy coating of molten coating metal, the steps of passing the article through a bath of molten coating metal whereby to coat it, and while the coating thereon is still molten passing the article into a bath of molten inert substance having a density substantially the same as that of the molten coating metal whereby to support the coating in molten condition and substantially free of gravitational influences so that said coating may become distributed by surface tensional effects, and solidifying said coating while so supported in said inert bath.

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