

[54] **HOT DIP COATING APPARATUS**

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[22] Filed: **Nov. 24, 1970**

[21] Appl. No.: **92,381**

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[30] **Foreign Application Priority Data**

July 8, 1970	Japan.....	45/60423
July 8, 1970	Japan.....	45/60424
July 8, 1970	Japan.....	45/60425
July 10, 1970	Japan.....	45/60956
Aug. 4, 1970	Japan.....	45/68582
July 8, 1970	Japan.....	45/69022

[52] **U.S. Cl.**.....118/5, 62/64, 118/68, 118/69, 118/423, 118/428, 165/40

[51] **Int. Cl.**.....B05c 11/00

[58] **Field of Search**.....118/5, 7, 8, 69, 125, 420, 118/419, DIG. 19, DIG. 20; 165/40; 62/64; 266/3 R, 4 A; 117/102 L, 102 M, 119.2, 119.4; 263/3 MA

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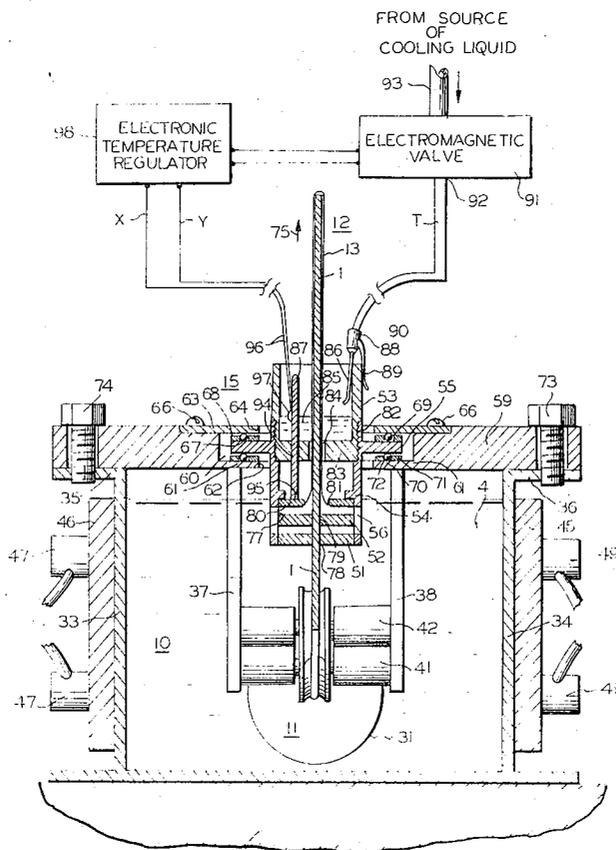
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[57] **ABSTRACT**

A hot dip coating apparatus for coating a metal wire or strip with a molten metal. A bath of molten metal has at least one guide member immersed therein. A cooling chamber is positioned above the guide member and has, at the bottom thereof, a bore through which the wire passes and also has a cooling liquid in the bottom thereof. A liquid supplier is attached to the cooling chamber, and a liquid level control means in the form of a monitor coupled to the liquid supplier keeps the liquid at a predetermined liquid level. The guide member and the cooling chamber are combined in a unitary body. The wire coated with the molten metal is cooled by the cooling liquid while passing through the bore while being guided by the guide member.

9 Claims, 4 Drawing Figures



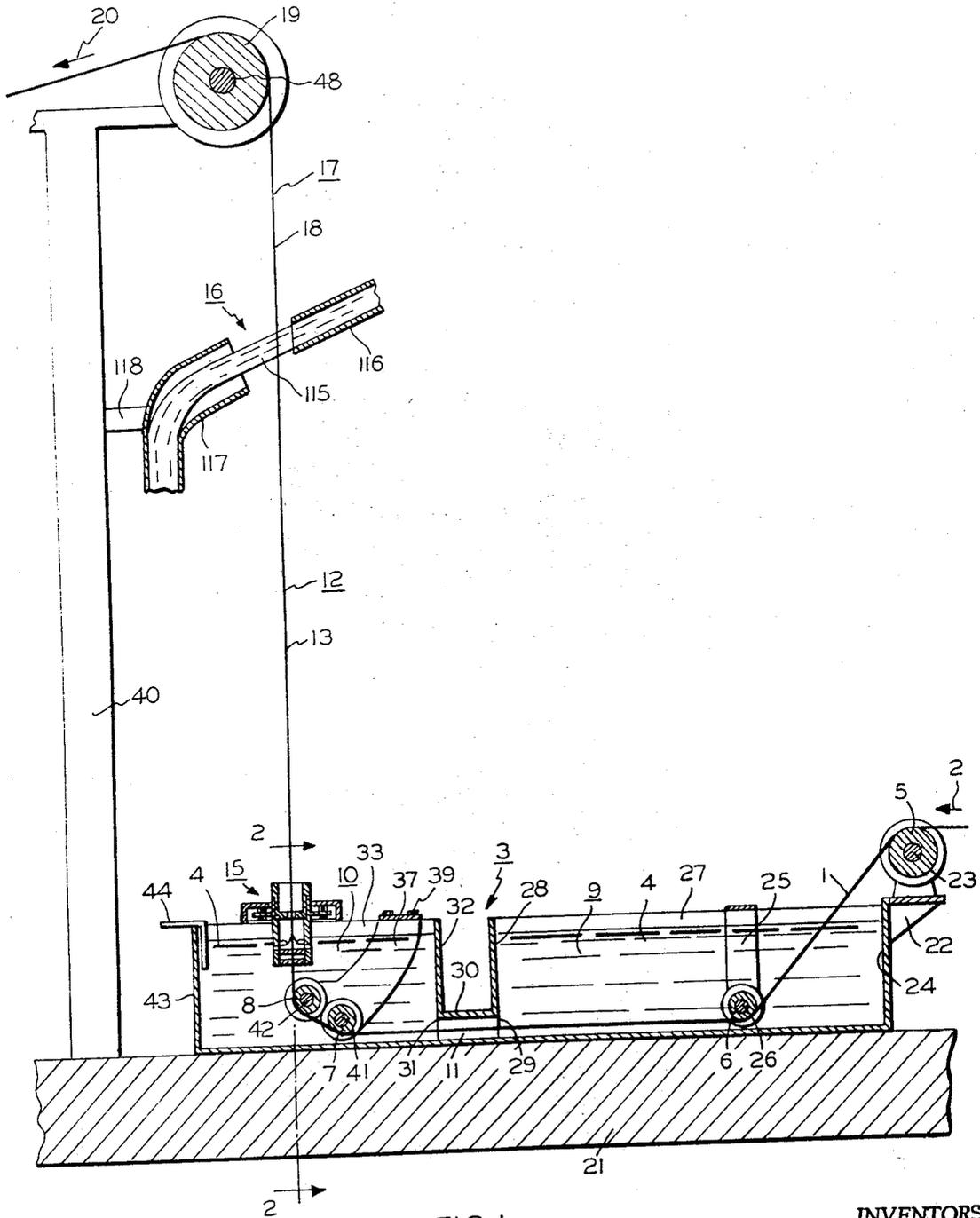


FIG. 1

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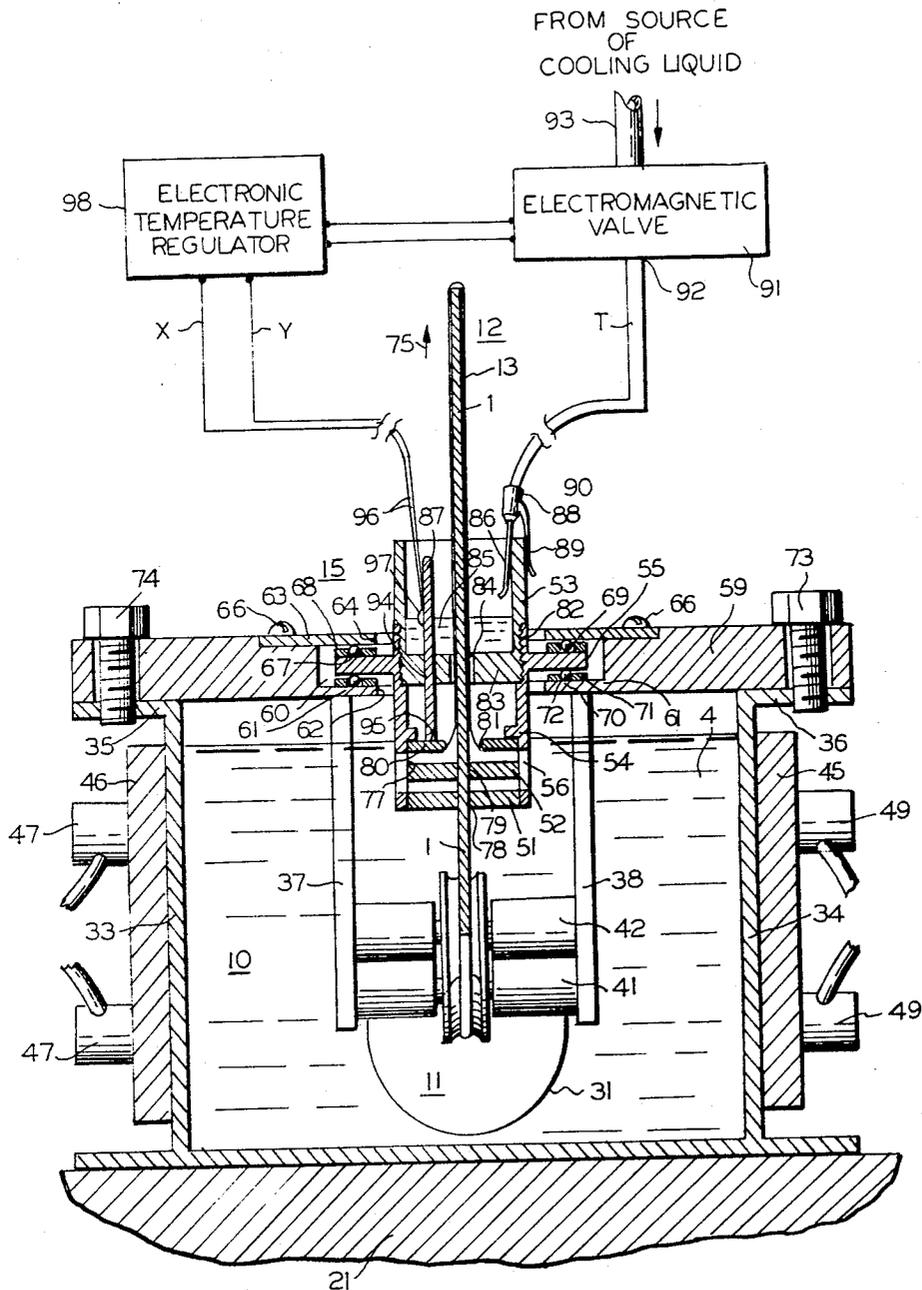


FIG. 2

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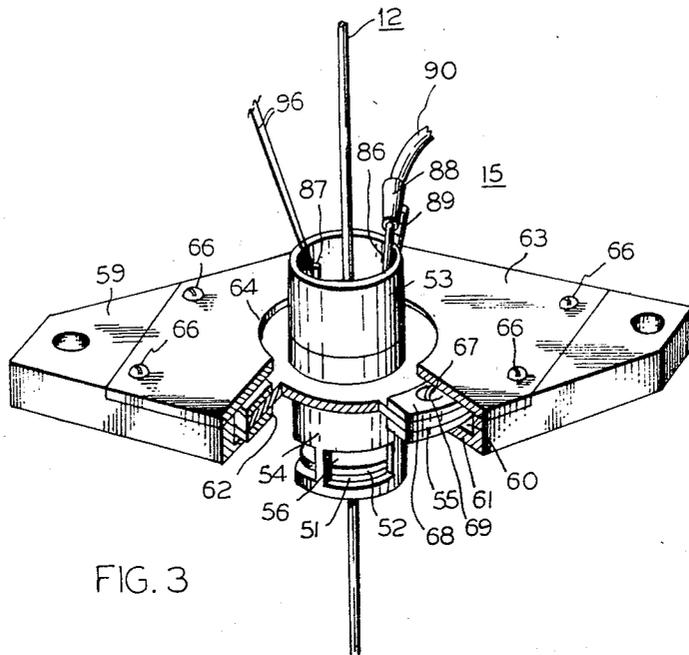


FIG. 3

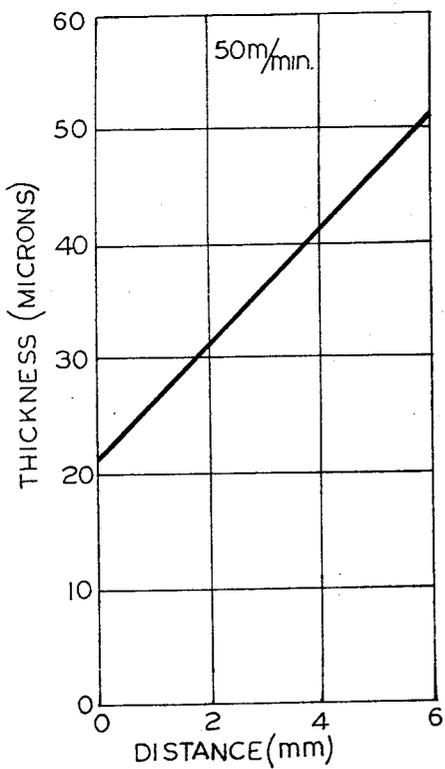


FIG. 4

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HOT DIP COATING APPARATUS

FIELD OF THE INVENTION AND PRIOR ART

This invention relates to a hot dip coating apparatus for coating metal wires or strips with a solderable metal layer.

The electrical circuitry for electronic equipment such as computers, radio and television sets, includes a number of electrical components such as resistors, condensers, transistors and packed integrated circuits. These components are attached to a circuit board and connected to each other by soldering, usually by dip soldering. It is necessary for reliable soldering that terminal leads of the electrical components have good solderability. The terminal leads are in the form of wires or strips plated with a tin-lead alloy. It is well known that good solderability requires the plating to have a thickness of more than 10 microns.

In the past, such wires and strips have been coated with a thick layer of plating by an electroplating method. However, it has been rather difficult to obtain consistently a thick layer of plating by conventional hot dip coating processes. An electroplated layer, however, is rather porous and not in an eutectic state. These conditions detract from good solderability. It is also difficult to produce by an electroplating process a layer which has a homogeneous composition consisting of a plurality of elements, such as tin, lead and bismuth.

OBJECTS AND SUMMARY OF THE INVENTION

An object of this invention is to provide a hot dip coating apparatus capable of coating a wire or a strip continuously with a solderable layer having a large thickness.

A further object of this invention is to provide a hot dip coating apparatus which makes possible controlling the thickness of the solderable coating layer.

A further object of this invention is to provide a hot dip coating apparatus which makes possible the manufacturing of a wire or a strip coated with a solderable layer having a desired composition.

These objects are achieved by providing a hot dip coating apparatus which comprises:

1. a bath of molten metal;
2. at least one guide member immersed in said molten metal;
3. a cooling chamber having, at the bottom thereof, a bore through which can be passed a wire or a strip, the cooling chamber having a cooling liquid in the bottom thereof;
4. a liquid supplier coupled to said cooling chamber; and
5. combining means combining the guide member and the cooling chamber into a unitary body. The wire or the strip coated with the molten metal is cooled by the liquid in said cooling chamber while passing through said bore while being guided by the guide member.

Further features of the present invention and a more thorough understanding thereof may be had by a consideration of certain embodiments of the present invention, which are described in the following specification and illustrated in the attached drawings.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 is a side elevation view partly in section of the overall apparatus according to the present invention;

FIG. 2 is a sectional view, on an enlarged scale, taken on line 2-2 of FIG. 1, illustrating a control device mounted on a molten metal bath forming part of the apparatus according to the present invention;

FIG. 3 is a perspective view, partly broken away, of the control device forming part of the apparatus according to the present invention; and

FIG. 4 is a graph showing an example of the relationship between the thickness of the layer coated on the wire and the distance from a bottom surface of a cover nozzle to the molten metal surface.

DETAILED DESCRIPTION OF THE FIGURES

For the purpose of simplicity, the hot dip coating apparatus is herein shown and described as being adapted to coat a copper wire with a tin-lead solder alloy, which coated wire can readily be used for terminal leads for electrical components such as resistors, condensers, and transistors. However, it will be apparent that the apparatus is readily adaptable to the coating of a strip metal body with various metals and alloys without substantial modification of the construction of the apparatus.

Referring to FIG. 1, a molten metal bath 3 is divided into two parts, a first molten metal bath part 9 and a second molten metal bath part 10, which are in communication with each other through a channel 11. Said bath 3 is mounted on a base 21. A bracket 22 is secured to an end wall 24 of said first bath part 9. A guide pulley 5 is rotatably mounted on a shaft 23 on said bracket 22. A bracket 25 is secured to the two side walls 27 of the first bath part 9. Each of the side walls 27 has a conventional electric heater (not shown) attached to the outside thereof. A sinker roll 6 is rotatably mounted on a shaft 26 on said bracket 25. A metal pipe 30 connects the two molten metal bath parts 9 and 10 and defines channel 11. Pipe 30 opens into bath part 9 through opening 29 in end wall 28, and opens into bath part 10 through opening 31 in wall 32. The side walls 33 and 34 of bath part 10 have flanges 35 and 36 along the upper edge thereof, respectively (FIG. 2). Brackets 37 and 38 are fixed to the flanges 35 and 36 by set screws 39. Shafts 41 and 42 are mounted to said brackets 37 and 38. Sinker rolls 7 and 8 are rotatably mounted on said shafts 41 and 42, respectively. A thermocouple 44 is coupled to a conventional electronic temperature regulator (not shown) to maintain the molten tin-lead alloy at a precise predetermined temperature. Electric heater strips 45 and 46 are attached to side walls 34 and 33, respectively (see FIG. 2). Terminal leads 47 and 49 are connected with the electronic temperature regulator so that said electric heater strips 45 and 46 are actuated by said electronic temperature regulator in association with said thermocouple 44.

A control device 15, to be described in detail hereinafter, is mounted on the second bath part 10 above sinker roll 8.

The molten tin-lead alloy 4 in the first molten metal bath part 9 is heated by the electric heaters on the side walls 27 and maintained at a predetermined temperature close to the temperature of the molten tin-lead alloy 4 in the second molten metal bath part 10. The molten tin-lead alloy 4 contained in the second molten metal bath part 10 is heated and maintained precisely at a predetermined temperature. Since the second molten metal bath part 10 has a small capacity, it is rather easy to control precisely the temperature of said molten tin-lead alloy 4 of said second molten metal bath part 10.

In operation, a wire 1 of electrolytic copper is fed from a conventional wire supplier (not shown) while being subjected to the necessary surface treatment. The wire 1 is passed into the first molten metal bath part 9 containing the molten tin-lead alloy 4 over the upper side of the guide pulley 5. Then said wire 1 is guided beneath the sinker roll 6 and passed through the channel 11 to the second molten metal bath part 10 containing said molten tin-lead alloy 4, passing under the sinker roll 7. After passing under said sinker roll 7 and under the sinker roll 8, said wire 1 runs upwardly through the control device 15 where said wire 1 is coated with a coating of said molten tin-lead alloy 4 of the desired thickness and is subsequently cooled. At the time, the cooled wire 12 has a coating 13 of the tin-lead alloy in a pasty state. Said wire 12 is passed through a secondary cooling means 16 and then cooled down to room temperature so that said coating 13 is solidified. After that, the wire 17 with the solidified coating 18 of said alloy on the surface thereof is passed over a guide pulley 19 and then is drawn to any suitable and available winding machine (not shown) capable of winding up said wire 17 in the direction shown by arrow 20.

Referring to FIGS. 2 and 3, the control device 15 comprises a housing 54 having two guide members 51 and 52 in the bottom thereof and spaced one above the other, and a cooling chamber 53 on the top of the housing 54. Said housing 54 is cylindrical in shape and has a flange 55 formed on the outer face thereof. The cylindrical wall of said housing 54 has large openings 56 at the bottom thereof so that the fresh molten tin-lead alloy 4 can flow into the interior of said housing 54.

The housing 54 is movably mounted on a supporting base 59 by means of the flange 55. Said supporting base 59 has a circular recess 60 in the center thereof and has a large circular opening 62 formed at the center of the bottom 61 of said recess 60. Said circular recess 60 is large enough to accept said flange 55 and is covered by a covering plate 63 having a large circular opening 64 formed at the center thereof. Set screws 66 extend through and fix said covering plate 63 onto said supporting base 59. Several ball bearings 67 are positioned between said covering plate 63 and the upper surface of said flange 55, and are held in position in holes 69 in a positioning ring 68 mounted on flange 55, the number of said holes 69 being equal to the number of said bearing balls 67. Several bearing balls 70 are positioned between the under surface of said flange 55 and the bottom 61 of recess 60, and are held in position in holes 72 in a positioning ring 71 on the bottom 61, the number of said holes 72 being equal to the number of said ball bearings 70. Said supporting base 59 is secured to the flanges 55 and 56 by screws 73 and 74. This arrangement makes it possible for said housing 54 to move freely in a true horizontal plane while the axis of said housing 54 is being kept in a true vertical position.

The two guide members 51 and 52 are fixed to the inner wall 77 of housing 54. The guide members 51 and 52 have respective guide holes 78 and 79 formed at the center thereof. The holes 78 and 79 have a diameter sufficient to allow the wire 1 to pass tightly therethrough. The two guide holes 78 and 79 are aligned essentially parallel to the center axis of the housing 54. Thus, said two guide holes 78 and 79 can guide the wire 1 in a direction substantially parallel to said center axis of said housing 54. Said two guide members 51 and 52 are preferably made of a hard steel such as die steel in order that they will wear well.

Said two guide members 51 and 52 can be replaced by a single guide member having a large thickness sufficient to guide the wire 1.

A cover nozzle 80 is provided which is in the shape of a disc and is fixed to the inner wall 77 of the housing 54. Said cover nozzle 80 has an opening 81 formed at the center thereof, the inner diameter of which is sufficiently large to pass the wire 1 freely. Said cover nozzle 80 is positioned above the guide members 51 and 52 and is essentially at the level of the surface of the molten tin-lead alloy 4 in the second molten metal bath part 10.

The cooling chamber 53 is in the shape of a cup, and is joined to the housing 54 by screw threads 82 formed on the outer surface thereof. Said cooling chamber 53 has a bore 84 formed at the center of the bottom 83 thereof. Said bore 84 is in exact alignment with the guide holes 78 and 79. Said cooling chamber 53 is preferably made of thermally insulating material such as polytetrafluoroethylene.

The wire 1, having a coating 13 of the molten tin-lead alloy 4 on the surface thereof, is passed and drawn up through said bore 84 in the direction of the arrow 75, said wire 1 being guided by said guide holes 78 and 79. A cooling liquid 85 is provided in said cooling chamber 53, the wire 1 being passed through the liquid 85 to cool said coating 13 on the wire 1 from the molten state into a pasty state.

It has been discovered according to the present invention that the leakage of said liquid 85 from said cooling chamber 53 through said bore 84 can be prevented by adjusting both the depth of said liquid 85 and the clearance between the inner wall of said bore 84 and said wire 1 having the coating 13 thereon.

The clearance which will prevent leakage is dependent upon the surface tension of said liquid 85. When said liquid 85 has high surface tension, such as water, said clearance can be about 0.15 mm. When the liquid 85 has a lower surface tension, said clearance should be less than 0.15 mm.

The depth of liquid which will prevent leakage is also dependent upon the surface tension of said liquid 85 and in practice ranges from 1 to 5 mm. Said depth is kept at a predetermined value by an automatic feed-back control means comprising a monitoring member 87 and a liquid supplier 86. As shown in FIGS. 2 and 3, said liquid supplier 86 and said monitoring member 87 are attached to the cooling chamber 53. Said monitoring member 87 is in a rod shaped member having approximately the same diameter as the wire 1, and is preferably made of the same metal as the wire 1. Said monitoring member 87 extends in liquid-tight relation through a bore 94 in the bottom 83 of said cooling chamber 53, and touches the cover nozzle 80 so that heat energy from said cover nozzle 80 flows upwardly through said monitoring member 87. A thermo-couple 96 is attached to said monitoring member 87 at a point 97 on the surface thereof. Said thermocouple 96 measures a temperature which is approximately the temperature of the coating 13 on the wire 1 at the level of the point 97. Said thermocouple 96 is coupled to an electronic temperature regulator 98 coupled to an electromagnetic valve 91 having an inlet 93 and an outlet 92. As one specific example, a Humphrey quick-dump valve can be used as said electromagnetic valve 91, which is made by Humphrey Products, Kalamazoo, Mich., U.S.A. Said inlet 93 is connected with a cooling liquid source (not shown). Referring to FIG. 2, the liquid supplier 86 is in the shape of a small tube having a mouth piece 88 and a clip 89 attached thereto. Said liquid supplier 86 is attached to the side wall of said cooling chamber 53 by said clip 89. A flexible tube 90 is attached to said mouth piece 88. The other end of said flexible tube 90 is connected with the outlet 92 of the electromagnetic valve 91. When said electromagnetic valve 91 is opened by the actuation of said electronic temperature regulator 98, said liquid supplier 86 feeds liquid 85 from the liquid source to said cooling chamber 53 through said inlet 93, outlet 92 and said flexible tube 90.

The control device 15 operates as follows. The temperature of the wire 1 adjacent the bore 84 is much higher than the boiling temperature of said liquid 85. Therefore, said liquid 85 evaporates due to absorption of heat energy from the wire 1 having the coating 13 thereon and from the monitoring member 85. The cooling rates of said wire 1 and said monitoring member 87 are proportional to the respective surface areas in contact with said liquid 85. A decrease in the depth of said liquid 85 results in a decrease in the cooling rates of said wire 1 and the monitoring member 87 and in an increase in the temperature at the point 97. The control of said liquid level of said liquid 85 makes it possible to maintain said coating 13 at a predetermined temperature at the level of said point 97. Such temperature regulation by an electronic temperature regulator by automatic feed-back control is described in many places in the literature, such as *Automatic Feedback Control*, written by W. Ahrendt and J.F. Taplin, 1951, McGraw-Hill Book Co., Inc., New York, Toronto and London.

The control device 15 operates in such a way that the wire 1 is drawn upwardly through the guide holes 78 and 79, the opening 81 and the bore 84 to the air. During this operation, said wire 1 is coated with a coating 13 which is initially in a molten state and subsequently cools to a pasty state. Said coating 13 is cooled mostly by absorption of heat by said cooling liquid 85 as latent heat of evaporation. It is, therefore, preferable to use a cooling liquid having a large latent heat of evaporation. Preferably the cooling liquid is a member selected from the group consisting of pure water, methyl alcohol, ethyl alcohol, and propyl alcohol. It has been discovered according to the present invention that when a preferred cooling liquid, as described above, has incorporated therein another chemical agent selected from the group consisting of glycerine, diethylene glycol, ethylene glycol, benzyl

alcohol, polyvinyl alcohol, and polyvinyl butylal, the resultant coating has a higher durability in a high temperature environment.

Even when said wire 1 vibrates mechanically, because the housing 54 is movably mounted on the supporting base 59, as described hereinbefore, it can follow the movement of said wire 1 so that the guide holes 78 and 79 guide said wire 1 so that it moves exactly in the direction of alignment of said guide holes 78 and 79 and the bore 84. Such an arrangement can prevent said coating 13 from being damaged by touching the inner wall of said bore 84.

After the treatment of the control device 15, said coating 13 is still in a pasty state. When said coating 13 is solidified slowly, the solidified coating has a spangled crystalline structure which is undesirable in some cases. It is preferred to employ a secondary cooling means 16, which rapidly cools said

The bath part 9 and the bath part 10 are filled with a molten tin-lead alloy having a composition of 30 weight percent of tin and 70 weight percent of lead. The second molten metal bath part 10 is maintained within about 1° of 290° C. The diameter of the guide holes 78 and 79 is 9.02 mm. The diameter of the opening 81 is about 2 mm. The diameter of the bore 84 is 1.20 mm. The wire running velocity is 50 meters per minute. The resultant thickness of the coating on the wire varies with the temperature of said molten tin-lead alloy and the wire running velocity. Besides these two factors, the other factor which has the greatest effect is the distance of the bottom surface of the cover nozzle 80 from the surface of the molten tin-lead alloy in the second molten metal bath part 10. An exemplary relation between said thickness and said distance is shown in FIG. 4. The effects of the composition of the cooling liquid 85 on the solderability are shown in Table 2.

TABLE 2

Liquid	After heating at 180° C. for 40 hours		Shelf-life test for 6 months	
	Color change	Solderability	Color change	Solderability
Glycerine, 10 weight percent	None	Excellent	None	Excellent
Water, 90 weight percent				
Ethylene glycol, 5 weight percent				
Water, 95 weight percent	do	do	do	Do.
Benzyl alcohol, 20 weight percent				
Methyl alcohol, 80 weight percent	Dark yellow	Fairly good	do	Do.
Distilled water				
Methyl alcohol				
Methyl alcohol	Slightly yellow	Good	do	Do.

wire 12 having said coating 13 thereon by a stream of water. Referring to FIG. 1, said secondary cooling means 16 comprises a jet of water 115 flowing from an outlet 116 to a receiver 117. Said outlet 116 is connected to any suitable and available water pump (not shown) by piping, in order that said water 115 can flow rapidly from said outlet 116 into said receiver 117 without falling to the second molten metal bath part 10. Said water is received by said receiver 117, and is discharged to the outside through piping (not shown). Said receiver 117 and said outlet 116 are secured to a supporting pole 40 by a bracket 118. Said wire 12 having said coating 13 which is still in the pasty state is passed through said jet of water 115 and said coating 13 is solidified rapidly thereby to a solid alloy having a eutectic structure.

It is further preferred to employ, in advance of said secondary cooling means, a compressing means to compress said coating 13 while it is in the pasty state. Such compressing means can be any available and suitable conventional pinch rollers.

When the hot dip coating apparatus according to the present invention is used for coating a wire with an elementary metal or an alloy having an eutectic composition, the secondary cooling means 16 can be omitted since such metals and alloys can be directly transformed from the molten state into the solid metal or alloy by cooling. For such uses, the temperature of the molten metal or alloy within the second molten metal bath part 10 is maintained at about 10° above the melting point temperature of the metal or an alloy so that the cooling liquid 85 in the cooling chamber 53 can quench the coating 13 of such metal or alloy and transform it from the molten state directly to a solid state.

Further features of the present invention and a more thorough understanding thereof may be had by a consideration of an exemplary operation of the hot dip coating apparatus embodying the invention and of exemplary results obtained by using said hot dip coating apparatus.

An electrolytic copper wire having a diameter of 1 mm. is initially surface-treated by a flux having a composition as shown in Table 1.

TABLE 1
THE COMPOSITION OF THE FLUX

chlorine	6.0% by weight
zinc	1.3% by weight
ammonium	0.3% by weight
surfactant	1.0% by weight
water	91.4% by weight

The hot dip coating apparatus according to the present invention has been described as being adapted to coat a copper wire with a tin-lead solder alloy. However, the apparatus is readily adaptable for coating a metal strip body with any desirable metal or alloy without substantial modifications in the construction of the apparatus. In such a case, the guide holes 78 and 79, the opening 81, and the bore 84 are made similar in shape to the cross section of the strip body.

While a particular embodiment of this invention has been shown and described, it will, of course, be apparent that various modifications may be made without departing from the invention.

What is claimed is:

1. A hot dip coating apparatus for coating metal wire or strip with molten metal, comprising:

1. a bath for molten metal;
2. at least one guide member disposed in said bath at a level to be immersed in molten metal in said bath for guiding wire or strip in a generally vertical direction;
3. a cooling chamber disposed above said guide member and having in the bottom thereof a bore for passing wire or strip therethrough, said chamber having a cooling liquid therein, and said bore of a dimension so that surface tension retains said liquid in the chamber;
4. a tubular member supporting both said guide and said chamber therein in an aligned vertical arrangement;
5. a peripheral flange element extending transversely from said tubular member;
6. a closure element disposed above said bath and having a control bore therethrough and a peripheral slot in the bore wall, whereby to slidably receive said flange;
7. said flange and slot being so dimensioned whereby the fixed assembly of said tubular support member, said cooling chamber and said guide means are laterally free floating; and

8. a cooling liquid supplier on said cooling chamber for supplying cooling liquid to said cooling chamber, whereby wire or strip, while being guided by said guide member, is coated with molten metal from the bath and then is cooled by said cooling liquid in said cooling chamber after passing through said bore into said cooling chamber.

2. A hot dip coating apparatus as claimed in claim 1 further comprising liquid level control means in said cooling chamber and coupled to and controlling said cooling liquid supplier to supply cooling liquid to keep a predetermined depth of cooling liquid in said cooling chamber.

3. A hot dip coating apparatus as claimed in claim 2 in which said liquid level control comprises a monitoring

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member in said cooling chamber which detects the temperature of the coated wire adjacent to said liquid and which is coupled to said cooling liquid supplier to cause said cooling liquid supplier to supply sufficient cooling liquid to maintain said temperature at a predetermined value.

4. A hot dip coating apparatus as claimed in claim 1 wherein said guide member includes a guide having a bore therethrough through which the wire or strip is guided and a cover nozzle mounted above and spaced from said guide.

5. A hot dip coating apparatus as claimed in claim 1 wherein said bath has two parts and a pipe is connected between said two parts adjacent the bottoms thereof to provide a channel of molten metal between said parts.

6. A hot dip coating apparatus as claimed in claim 1 wherein said cooling liquid consists essentially of a liquid having large latent heat of evaporation.

7. A hot dip coating apparatus as claimed in claim 6 wherein said liquid consists essentially of one member selected from the group consisting of pure water, methyl alcohol, ethyl alcohol, and propyl alcohol.

8. A hot dip coating apparatus as claimed in claim 7 wherein said liquid further includes one member selected from the group consisting of glycerine, diethylene glycol, ethylene glycol, benzyl alcohol, polyvinyl alcohol, and polyvinyl butylal.

9. A hot dip coating apparatus as claimed in claim 1 which further comprises a secondary cooling means mounted above said cooling chamber for cooling the coated wire down to room temperature.

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