

May 25, 1943.

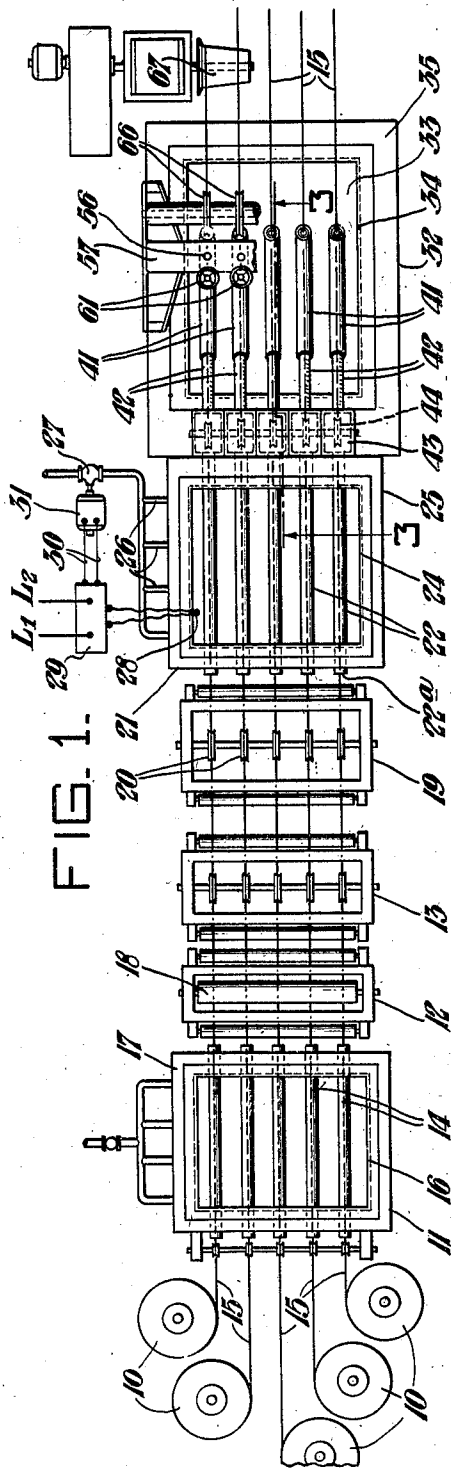
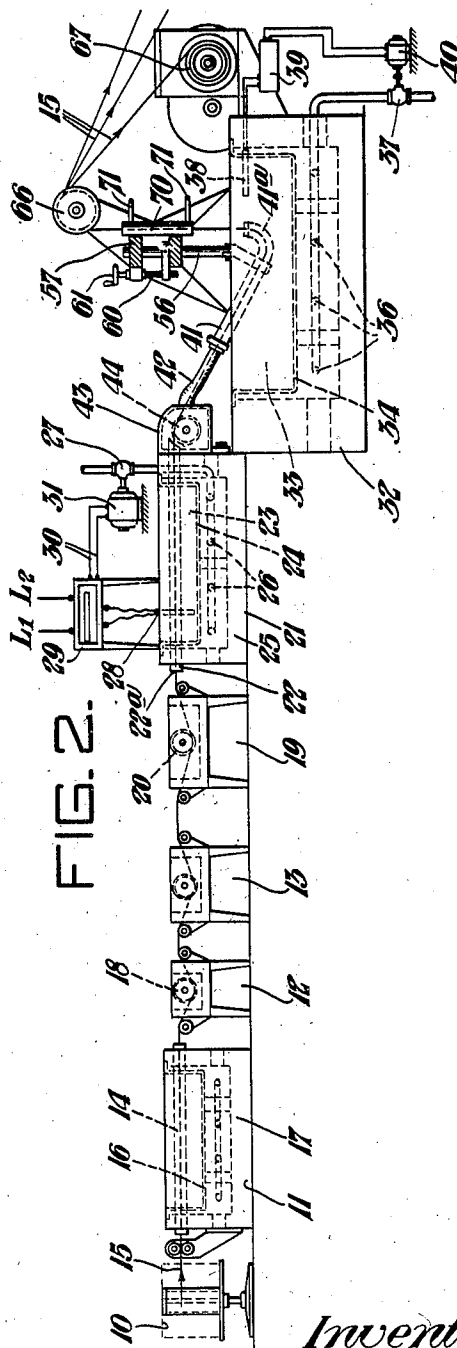
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2,320,129

METAL COATING

Original Filed June 23, 1939

4 Sheets-Sheet 1



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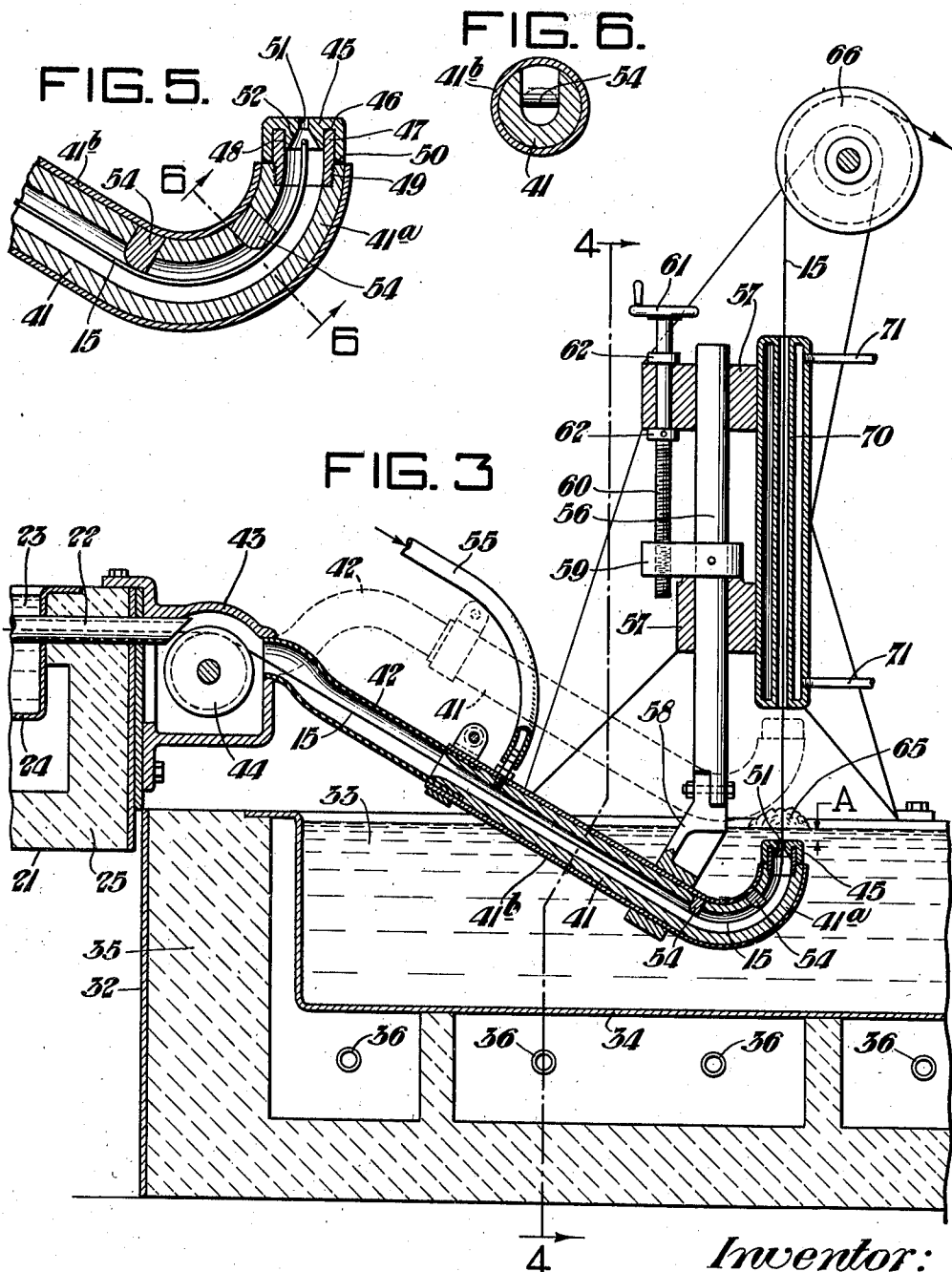
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METAL COATING

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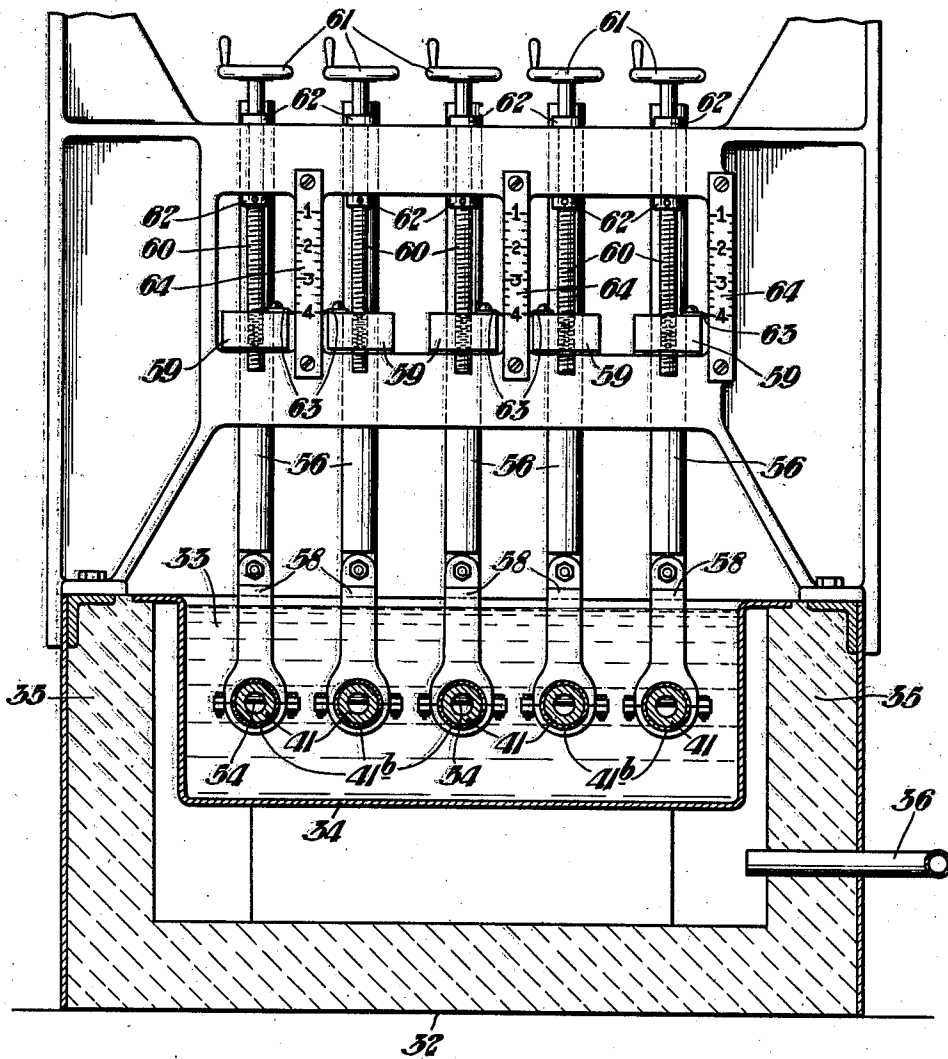
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METAL COATING

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4 Sheets-Sheet 3

FIG. 4.



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4 Sheets-Sheet 4

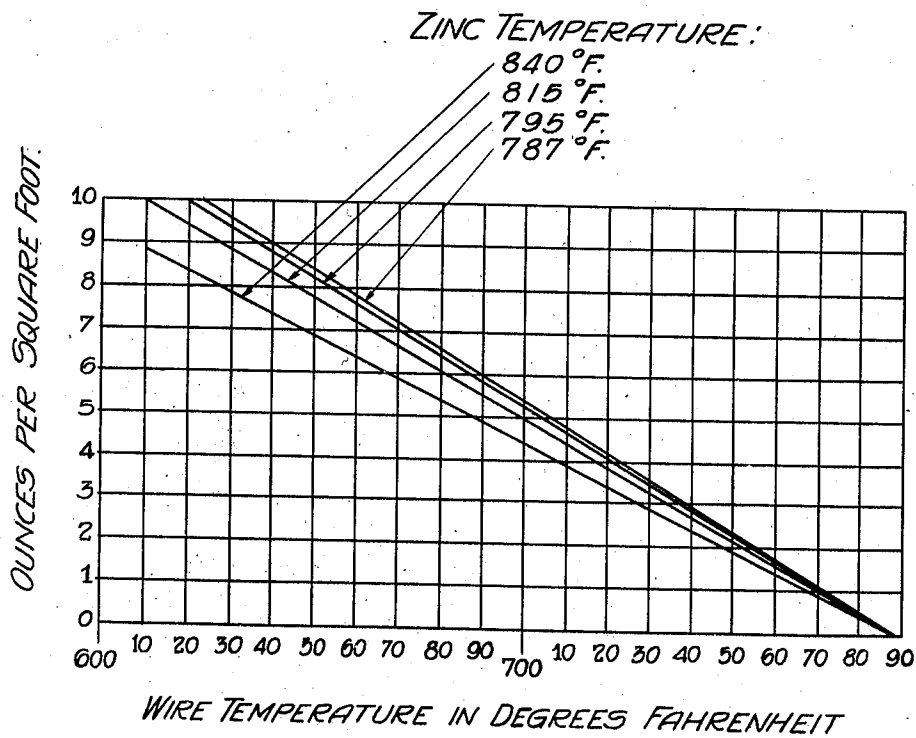


FIG.—7.

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UNITED STATES PATENT OFFICE

2,320,129

METAL COATING

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Original application June 23, 1939, Serial No. 280,895. Divided and this application March 14, 1940, Serial No. 324,011

10 Claims. (Cl. 91—12.5)

This invention is concerned with the coating of one or more metals on another metal of like or dissimilar properties by the so called "hot-dip" method, this term being used in the sense that the coating metals are molten when applied.

One common metal coated product is galvanized steel wire, and so the manufacture of this product has been adopted herein for illustrative purposes. However, it will be understood that wherever wire is hereinafter mentioned, strip, sheet, bar, rod or prefabricated stock (nettings, screens, grilles, ropes, cables, etc.) are contemplated in certain instances, it being recognized that any skilled mechanic could make changes in the specific apparatus shown in the drawings hereof to convert the apparatus for the accommodation of such articles, whereby they could be coated in accordance with the teachings of the present invention. Therefore, in the following description and claims, it is to be understood that the invention should not be limited exactly to what is specifically disclosed.

Hot-dip coating operations have, in the past, been carried out with the object of either coating without bonding the coating to the base or to both coat and bond the coating to the base. The former would be illustrated by immersing the article to be coated in a bath of coating metal, and then withdrawing it with a covering of the bath metal adhering to it in much the same way as molten paraffine adheres to a stir rod, or paint to a stick, there being no chemical bond or alloy bond between the coating and the coated article. The other type of operation, and the one usually sought in galvanizing, is that wherein a chemical or alloy bond is obtained between the substances. As will be seen hereinafter, the present invention is, in its different phases, capable of embracing either of these types of operations, and that it is particularly well suited to the production of coatings of the latter type or, in other words, bonded coatings.

According to the present invention, coating is effected by immersing base metal in molten coating metal for one relatively short dip, after the base metal has been thoroughly cleaned and preheated a predetermined amount approximating or less than the temperature of the coating bath. Though the use of a flux might be advantageously used in the coating of some metals, the in-

vention does not necessarily require the use of a flux as heretofore known to the art. This is because the invention provides for the preparation of the base metal and the coating metal so that when the two are brought into contact, there exists a state of greatest affinity therebetween. Due to such preparation, and the perfected mode of bringing the coating and coated substances together, a very short immersion is possible. Only one dip in a bath of any given metal is required to provide the dipped article with a coating of the metal, and, in any one coating operation, there need only be a plurality of dips when there is a plurality of different metals to be coated in superimposed relationship.

Among other features of the invention is that of coating base metal with another metal while maintaining the surface of the former substantially free from oxygen. Other features include controlling the exact thickness and concentricity of the coating on a wire or other base article; casting an extraordinarily heavy metallic coating on a wire or other base article in a single dip or immersion; continuously casting a metallic coating on a wire or other base article, when the surface metal of the latter, and the coating metal, do not form a chemical or alloy bond; and coating a metal wire, or other article, with an unlike metal that will alloy therewith, and controlling the thickness and character of the alloy layer formed therebetween.

The processing features outlined above involve the use of certain apparatus. This apparatus comprises means for introducing a wire directly into bright metal beneath the surface of a molten bath of the metal, including means for effecting an immersion of a wire into a bath of coating metal to a predetermined extent, and means for effecting the immersion of wire, or other elongated metal stock, without subjecting it to bends of appreciable magnitude or abruptness, during its contact with the coating metal or immediately after its emergence therefrom.

Referring to the accompanying drawings:

Figure 1 is a plan of coating apparatus suitable for carrying out one particular application of the present invention;

Figure 2 is an elevation of the coating apparatus illustrated in Figure 1;

Figure 3 is an enlarged section of a portion of

the apparatus illustrated in Figures 1 and 2, taken from the line 3—3 in Figure 1;

Figure 4 is a section taken along line 4—4 in Figure 3;

Figure 5 is an enlargement of a detail of the apparatus shown by Figure 3; and

Figure 6 is a section taken from the line 6—6 in Figure 5.

Figure 7 illustrates a graph recording an empirical determination of the effect of the temperatures of the wire and fused bath on the amount of coating metal cast.

Referring more particularly to the drawings, it is contemplated that the wire be annealed, if desired, and cleaned. The annealing furnace 11 shown comprises tubes 14, through which the wires 15 pass from reels 10. The tubes are submerged in a lead bath contained in a pan 16, supported in a suitable furnace setting 17 for heating the bath. The cleaning may be either by heated or cold hydrochloric or sulphuric acid contained in a suitable vat 12 provided with a sinker or submerged roll 18 for causing the desired immersion of the wire. Thereafter the wire is passed through a water wash 13, which removes any acid remaining thereon.

Other heat treating and cleaning processes may be used before coating a wire in accordance with the process of this invention. For instance, the wire might be passed through a molten electrolyzed salt bath, which will anneal and clean the wire at the same time, thus replacing the equipment shown at 11 and 12.

It might be that the water of the water wash 13 will be so high in total solids as to form a residual film on the wire when the water is evaporated therefrom. This will adversely affect bonding between the base wire and the cast coating, and, therefore, it may be desirable to provide a heated water wash 19 that is low in total solids, for instance, a distilled water wash. A sinker roll 20 provides proper immersion of the wire in the bath 19. If the water bath 19 has been maintained at a suitable temperature, the water remaining on the wire will be evaporated so that the wire will be substantially dry just as it enters the next succeeding apparatus of the train.

This next succeeding apparatus provides for preheating the wire in a controlled atmosphere by controlled heat up to a certain temperature that must be related to the temperature of the coating bath to attain predetermined coating results. The preheater may be constructed and arranged in any suitable way compatible with the principle upon which the invention is based, which is that a wire or other metallic object, if suitably cleansed and preheated, so that the average temperature of its mass is at least slightly less than the temperature of the coating metal will, when introduced into the latter, have a solid coating practically instantly formed (frozen or cast) thereon, which coating will become firmly bonded to the wire or object by means of an alloy or chemical compound layer between the coating and coated substances, and composed of each. Under ideal conditions, this effect may be obtained when the preheated base metal has been exposed to the coating metal for as short a period of time as $\frac{1}{20}$ of a second. If the surface of the base metal is at the temperature of the coating metal when introduced thereto, and if the proper surface condition is had on the base metal whereby it is free of contamination from foreign matter, an alloy will, in most cases, be formed in-

stantly. The bath metal will tend to maintain the surface of the base metal at this temperature for a sufficient time to permit an alloy to be formed even though the interior of the mass of base metal is cooler than the temperature of the bath so that the heat transfer is from the latter to the former. This transfer exerts a cooling effect upon the surrounding coating metal so that an amount, determined by the temperature differential between the base metal and coating metal, and their thermal characteristics, solidifies upon the base metal. This cast layer of bath metal may be retained in its entirety if the wire is withdrawn from the bath before the heat absorptive capacity of the base metal is exhausted. Otherwise, some, or all, of the cast coating will be sacrificed, depending upon the length of time the coated wire is left in the bath.

In cases where the wire is appreciably cooler than the coating bath, or relatively cold, it will, upon being immersed in the coating bath, cause a large mass of coating metal to congeal thereon without an attendant alloying action. Let it be assumed that the heat transfer from the coating metal to the base metal during this immersion is sufficient to elevate the temperature of the surface of the base metal to or above that point at which alloying of the two metals, or their mutual solubility, commences. Then, if the wire's surface has been properly cleansed, and if the wire has been submerged directly into the bright metal of the bath so that none of the contamination ordinarily at the meniscus (usually an oxide film) engages it first, an alloying action will commence as the coated wire is withdrawn from the bath, (even though both metals are in the solid phase), which alloying will continue so long as the residual heat remains sufficient to support this action. With the coating metal and the base metal in intimate contact, it has been found that so long as residual heat under these conditions lingers in the coated wire to maintain the temperature at or above that at which alloying takes place (in the case of zinc and iron, the temperature above which alloying takes place, with the two metals in the solid phase, is approximately 200 degrees centigrade, or 392 degrees Fahrenheit), an alloy will be continuously formed by the two metals so long as this temperature is maintained. In such cases, it is possible by quenching the coated wire upon its emergence from the bath, and by varying the elapsed time between emergence and quench, to effect a precise control over the alloy layer formed between the coating and coated substances. Also, according to a teaching of the invention, heaters may be provided to maintain or increase the heat in the wire until the alloying action has been carried to an increased amount.

It will be seen from the foregoing that the preliminary controlled preheating of the base metal is directly determinative of the character and extent of coating ultimately obtained, and that this control may be supplemented or complemented by treatment of the base metal after coating to remove, preserve, or enhance the residual temperatures so as to critically determine the extent of the alloy formed between the coating and base metals. The nearer the base metal is preheated to the melting point of the coating metal, the more alloy and the less pure coating metal will be obtained thereon upon immersion therein, and vice versa. Thus, if the base metal is preheated to or above the melting point of the coating metal, an alloy will be formed, and only

that amount of pure coating metal retained thereon as is allowed by surface tension (a wash of pure metal). Of course, various arrangements of preheating may be used so long as satisfactory control in keeping with the foregoing can be maintained. In hot-galvanizing, it is desirable to complete the drying and heating (i. e., preheating) of the wire in a nonoxidizing atmosphere, which may be of a reducing or neutral character.

A satisfactory form of preheater is illustrated by the drawings, and comprises one or more tubes 22 submerged in a lead bath 23, contained in a pan 24, which is supported in a suitable furnace setting 25 so that the lead may be heated. The lead bath 23 is subjected to close temperature control by the controlled use of a fuel such as gas or oil, which is introduced to the combustion chamber beneath the pan 24 through one or more pipes 26. The flow of fuel is controlled by a valve 27, which is rendered automatically responsive to the temperature of the bath 23 by means of a thermocouple 28 connected to a potentiometer 29. The potentiometer controls the flow of electricity from a source L_1 — L_2 through wires 30 to a motor 31, which operates the valve 27. This arrangement is such that as the temperature of the bath 23 rises, current is supplied to the motor 30, which causes the valve 27 to close, thus shutting off the fuel supply, causing the temperature of the bath to be lowered. Upon cooling, heat is again applied to the bath by the thermocouple actuating the potentiometer to energize the motor 30, which opens the valve 27. Thus, the flow of fuel is resumed and the temperature of the bath is again restored. The setting of the potentiometer thus controls the temperature of the lead bath.

As has been mentioned, it is desirable to prevent oxidation of the clean wire. Though any suitable means may be employed for this purpose, I prefer to use a nonoxidizing atmosphere, which is supplied through a conduit 55 into a tube 41 intermediate its ends. The gas then fills the tube 41, the conduit 42, the box 43 (all of which will each be presently described), and the tube 22. The end 22a of the tube 22, where the wire enters, may be partly closed, or, in any case, so arranged that sufficient gas enters the system to prevent entrance of air at 22a. If the gas used is combustible, it may be allowed to burn at the point 22a to indicate that an excess is present in the tube 22.

The wire passes from the preheater 21 into the coating bath 32. This coating bath is a zinc bath 33 contained in a pan 34. Since, in the practice of the present invention, a much smaller supply of bath metal is required than usual, pans of carbonaceous or other special materials immune to attack by the coating metal, may be used. Temperature control may be exercised over the coating bath in the same manner as that described above in connection with the lead bath of the preheater, although manual control with the aid of a temperature indicator is satisfactory for most purposes. In the drawings, there is illustrated a thermocouple 38 and a potentiometer 39 controlling a motor 40, which actuates a valve 37 in a manner analogous to that of the preheater control already described. Other heating arrangements for the coating bath are possible, as, for instance, in the case of copper coating, the copper may be melted in a crucible using induction currents.

The base metal may be introduced into the

coating metal in such a way that it is protected from heating or other contact with the bath metal, until it reaches a position beneath the surface of the latter where the bath metal is bright, free from contamination, and in the state of highest affinity for the base metal, and so that the base metal follows a predetermined path of travel of accurately determined distance through the molten bath from its point of initial contact therewith until its emergence therefrom at the meniscus or surface.

To accomplish this, a tube 41 is provided having a curved portion 41a at one of its ends. At the other of its ends the tube is connected by a flexible conduit 42 with an air-tight box 43 which accommodates a guide sheave 44 adjacent the end of the preheating tube 22, leading the wire down through the tube 41.

Where the tube 41 is formed of iron or steel, and the bath is one of zinc, to prevent the contamination of the latter by the former, tungsten sheet 41b may be used to sheath the tube so as to protect it against the action of the molten zinc. In this connection, it has been discovered, and is believed to be disclosed here to the art for the first time, that tungsten, tungsten carbide, and tantalum carbide are inert to molten zinc, and, at the temperatures contemplated herein, do not react therewith in any way, so that in addition to sheathing the tube 41 to protect it from the bath metal, a similar sheathing may be advantageously applied to the walls of the pot containing the bath metal if this be ferrous material and if the fused bath be zinc. Such sheathing may be in the form of thin metal sheets, spot welded to the walls and bottom of the container, or the resistant metal may be impregnated into the surface of the walls, employing atomic hydrogen methods; also by pulverulent, or electrolytic deposition. However, successful galvanizing has been carried out without using any materials in the construction of the apparatus other than iron or steel.

The end 41a of the tube 41, which is submerged in the coating bath, is provided with a suitable wear and heat resisting die, which permits outward passage of the wire without ingress of molten metal into the tube. This die may be formed from any substance that will resist the action of molten zinc or any other substance included by the coating bath. It is possible to use an iron or steel die. Obviously the die substance may be of any of the specific materials disclosed above as being inert to molten zinc.

An annular groove 46 is provided in the die and a sleeve 47 is brazed thereto. Inter-engaging threads 49 on the sleeve 47 and tube 41 permit the end piece to be screwed into position. A shoulder 50 is arranged to form a substantially tight joint which is effective to protect the brazed joint 48 from the destructive action of the bath.

An orifice 51, of the general shape and size of the cross section of the base metal it is to accommodate, is provided somewhere in the central region of the packing member. This orifice, though closely conforming to the outer surface of the base metal to pass therethrough, may be of a size to afford a clearance of .002 inch which is of sufficient size to prevent undue wear, and, yet, in the case of molten zinc, is sufficient to preclude the entry of bath metal into the tube even when the base metal is stationary. A clearance of .010 inch will prevent zinc from entering the tube so long as the base metal is emerging therefrom at speeds usually encountered in con-

ventional coating practices. To facilitate threading a wire through the tube and orifice, an internal slope or funnel-shaped entry is imparted to the orifice walls, as at 52. Guides 54 serve to carry the wire around the bend in the tube and relieve the latter from wear. The inert atmosphere inside the tube, introduced in the manner already described maintains the coating metal overlying the orifice of the packing at the submerged end of the tube, in bright condition, free from contamination by oxides, etc.

Since the length of time in which the base metal is exposed to the coating metal is effective in determining to what extent the heat absorptive capacity of the base metal is lost, and, hence, determines the extent of pure coating metal cast thereon, and since it also determines the residual heat of the coated body after it emerges from the bath, and, thus, determines the extent of the progression of alloying action after emergence from the bath, and, in some cases, determines the extent of alloying when this is accomplished with the coating metal in the liquid phase, it is extremely important that the extent of immersion, (i. e., the distance A at which the orifice 51 of the tube 41 is disposed beneath the surface of the bath), be capable of accurate adjustment and control. Therefore, means should be provided for raising and lowering the tube 41 so that the distance A may be changed or fixed in any desired position to give the character of coating desired.

An illustrative structure for the above purpose is shown in the drawings, and comprises a bar 56, slidably mounted for vertical movement in a fixed frame 57. The bar supports a bracket 58 at its lower end which, in turn, is secured to the tube 41. Fixed on the bar 56 is a bracket 59. Rotatably mounted in the frame 57 is a shaft 60 provided with a handwheel 61 confined against vertical movement by collars 62. The shaft 60 has threaded engagement with the bracket 59, whereby the rotation of the shaft 60 by the wheel 61 raises and lowers the tube 41. A pointer 63 is secured to the bar 56 for accurately indicating on a fixed scale 64 the position or distance of the orifice 51 from the surface of the coating bath, which, as has already been explained above, determines the extent of immersion of the object being coated.

A wiper 65 of charcoal, coke and sand mixed with paraffine and tallow, or any of the common methods and materials that will keep the surface of the coating bath in bright, non-oxidized condition, may be provided at the point where the object being coated emerges from the bath. Due to the confining of the wire in the die orifice 51, so that it is held to substantially one directional axis through the bath, and because such axis, which extends from the packing orifice 51 to the surface of the bath, is usually very short, the wire will emerge from a substantially fixed point at the surface of the bath, which is a phenomenon commonly referred to in the art as the wire "keeping in its cone." This is an allusion to the phenomenon caused by adhesion of the coating metal to the moving wire. When this is continuous, a cone of bath metal appears to stand around the emerging base metal, and a good coating is to be expected.

One of the main advantages of the apparatus illustrated herein, is that it brings the coated object out of the coating bath at such an angle that any forces, such as gravity, adhesion, or other influences, which act on the unsolidified

portion of the coating comprising the superficial areas thereof, causing it to run, act thereon so that the finished coating is substantially concentric, free from surface imperfections, and devoid of lop-sided tendencies. Although any angle of emergence is as applicable in the case of the present invention as in prior art practices, nevertheless, for the aforementioned reasons, an angle between 45 degrees to the vertical, and most preferably the latter, is maintained.

The drawings illustrate a sheave 66 mounted in a bracket to guide the wire vertically from the bath, and to arrange for its being conducted in a straight line for a substantial distance. During this interval, the coating has time to "set" completely before touching any outside object or before being bent or flexed. In the case of zinc on iron wire, an alloying action will continue so long as the residual heat in the composite wire is such as to maintain a temperature at or above 200 degrees centigrade. For some types of coating the residual heat alone may not provide the requisite amount of alloy, and in other types, might provide too much. Hence, it is sometimes necessary that the wire be heated, or that its cooling be controlled after it leaves the bath, so that it can be subjected to more or less (as the case requires) heating up to the melting point of the coating. This may be done by passing the wire through a heated tube 70 having a jacket to which is supplied a cooling or heating medium through pipes 71. By the application of either heat or cold the alloying action is arrested, retarded, maintained, or accelerated, as may be desired.

From the sheave 66, the wire may be conducted to any point of storage or subsequent processing. Usually it will be wound on a take-up block such as is shown at 67. If it is desired to work the coating, as by passing the wire through a die, or, in the case of other metal objects, through work rolls or forging means, to produce certain physical results, a die, or other working medium, may be arranged at some point along the path of travel of the coated base metal so that the latter may be worked before being wound on a take-up block, or otherwise disposed of. If hot working is desired, the working means will be disposed near the coating bath so that, in the case of zinc, the temperature of the coated base metal will be somewhere from 100 degrees centigrade to 150 degrees centigrade. If cold working is desired, the work means may be positioned next adjacent the take-up block, or other storage means, at which point most of the heat in the coated object will have been dissipated into the air.

In cases where there is no alloying action, as when molten lead is cast onto iron base wire, the lead resembles a sleeve or pipe shrunk upon the base metal, but not alloyed thereto. In this case, a bond may be formed by drawing, or otherwise working, the coated article, which is comparable to the best iron-lead electroplated bond. Such a bond is made possible by the state of cleanliness of the base metal when introduced to the coating metal, so that there is nothing to inhibit crystalline interpenetration when the coating and the base metals are simultaneously worked.

In actual practice, it will be understood that a plurality of wires are treated simultaneously, as shown in Figure 1. In such cases, each wire is handled exactly in the same manner as that already described hereinbefore. Only one bath is

required at 11, 12, 13, 19, 21 and 32, but where the tubular conduits are used, it is preferable that each wire have a separate tube. This enables individual controls to be supplied for regulating each one of the tubes 41, whereby each wire may be controlled separately to vary the character of coating produced thereon.

In accordance with the present invention, a plain low carbon steel wire, substantially devoid of phosphorous, or silicon, and with an uncarburized or unnitrided surface, can be coated with several ounces of zinc, the preponderance of which coating is substantially pure coating metal without the aid of any flux whatsoever, so that the resultant article, when cold worked by drawing through a die to produce a reduction of 50 per cent or less, will stand the conventional button test without any signs of failure. This invention also enables such a plain low carbon steel wire to be zinc coated with three ounces or less per square foot in which case the coating is sufficiently ductile to stand a button test without any drawing. This phase of the invention is important in the production of wire for telephonic and telegraphic current transmission.

The reason underlying such successes of the present invention, as outlined above, may be explained as follows: In all known methods of hot-galvanizing, an alloy layer or bond is formed on the steel. If this layer is sufficiently thin and of the proper chemical and physical composition, the coated wire will pass a button test. If this alloy layer is too thick, or of improper chemical composition, the coated wire will not pass a button test. The time and temperature of immersion under previously known coating processes permit formation of a brittle alloy layer on plain low carbon wire in objectionable amounts, while in accordance with the present invention the disclosed preparation and proper control of time and temperature effect the formation of a less brittle alloy.

In accordance with the present invention, a wire at a predetermined temperature is passed into a coating bath at known temperature, the wire being of a metal having a known definite thermal capacity, or specific heat, whereby a given weight of metal of the wire at a predetermined temperature has the capacity to chill a definite quantity of the coating metal into a state of solidification. For convenience, this capacity can be referred to as "chilling potential" of the base metal. The length of time of passage of the wire through the coating bath is, according to the present invention, subject to such regulation and control, so that the chilling potential of the wire may be exercised to cast on a coating in just such an amount as was predetermined and desired.

As an example of this, three ounces of zinc may be cast on a wire of a plain, low carbon stock, or of high carbon stock, with the wire being in contact with the molten zinc approximately one-sixth of a second. Whether the stock be high or low carbon, or high or low with other metals or metalloids, the alloying action may be critically controlled by prolongation of the residual heat, as by the application of outside heat to the wire; or, by the rapid diminution of residual heat, as by the application of cooling means; such as a quench applied after any elapsed interval of time after the wire's emergence. Under these conditions, the metals do not have time to form an excessive amount of the brittle alloy compound.

It will be understood that, depending upon the kind of metals comprising the coating and coated substances, and depending upon the time of immersion and the relationship between the temperature of the coating bath to the temperature of the base metal as it is being immersed therein and conducted therethrough, the alloying action may start and end within the immersion period; or, it may start within the immersion period, and continue on after emergence from the bath; or, it may not commence until after the emergence from the bath, when the several metals entering into the metallic union are each in the solid phase.

To illustrate the workings of the apparatus and method hereinbefore set forth, a brief resume of the objectives and operations thereof will now be given, accompanied by actual examples to better illustrate the invention. First, it is proposed to cast a set amount of metal of the molten bath on a preheated base wire, or other article, having a prepared surface, by having a sufficiently short depth to allow the chilling potential of the wire, or other article, to be dissipated to the point of casting the desired coating, and, then, by immediately causing the wire to emerge from the bath. In any given case, after the wire has been threaded through the entire apparatus and the temperatures of baths 23 and 33 have been adjusted at predetermined points, wire is started running by rotating the take-up block after which, by regulating the length of the immersion A, the desired thickness of coating may be exactly controlled. This can be done by checking the coated wire with micrometer calipers. If necessary, the temperature of the preheating bath 23 may be reset until the desired coating is obtained. The amount and kind of alloy layer or bond formed between the base metal and the coating metal depend entirely on the physical properties of the base wire and the molten bath.

As an illustration of one application of the present invention, a 10 gage, .132 inch diameter wire, preheated to an approximate temperature of 750 degrees Fahrenheit, traveling at a speed of about 30 feet per minute, was passed through molten zinc for the distance of one inch, representing a submersion time of .16— or $\frac{1}{6}$ of a second, and three ounces of coating per square foot of wire surface were concentrically cast thereon. As a matter of actual practice, it is extremely difficult to ascertain with exactitude the temperature of the wire at the time of its immersion; therefore, it is preferable to hold constant the speed and submerged travel of a particular size wire, and vary the temperature of the preheater until the desired amount of coating appears on the moving wire. Having once attained the desired preheated temperature, the results can be duplicated in all future work.

The distance the wire passes through the molten zinc has no theoretical lower limit, so long as enough coating metal is available adequately to wet the wire, and the speed of travel of the wire is proportionately slow. As a practical matter, however, an inch immersion has proved satisfactory; the speed of travel of the wire being regulated to this factor. The maximum distance of travel through the zinc is, however, advantageously limited to about three inches, since the speed of travel of the wire for immersions over this amount must be excessive, causing, if the base metal is at a temperature to effect casting, a rough coating to be acquired.

The following table gives a record of actual experiments conducted in the application of zinc to wires of the character and size indicated below the table, wherein all of the important variables, with the exception of the preheating temperatures, have been set forth, together with the results obtained therefrom:

20 or 30 feet represent the elapse of sufficient time to increase the alloy compounds to the point where they might be objectionable in some coating operations for some desired results. Therefore, the wire may be cooled immediately upon emergence from the coating bath by any of the common methods of cooling, such as by passing

Table A

Specimen No.	Atmosphere	Zinc temp., °F.	Immersion in zinc		Travel of wire, feet per minute	Oz. zinc cast, per sq. ft. wire surface	Dips in CuSO ₄ sol.	Average thickness alloy layer in inches
			Distance, in inches	Time, in seconds				
1.....	Nitrogen.....	792	1.25	.18	33.984	.54	3	.00032
2.....	do.....	798	1.25	.18	33.984	.685	3 ¹ / ₂	.000375
3.....	do.....	800	1.25	.18	33.984	.67	3	.00047
4.....	Hydrogen.....	805	.75	.13	28.800	5.30	18	.00012
5.....	do.....	805	.75	.13	28.800	4.57	16	.00012
6.....	Natural gas.....	800	2.25	.39	28.800	5.625	20	.000205
7.....	do.....	805	2.25	.39	28.800	7.65	27	.00025
8.....	Nitrogen.....	805	2.00	.29	34.560	.44	2	.00023
9.....	Air.....	800	2.00	.43	23.040	14.30	46	No alloy

Other essential data:

Specimens Nos. 1-6, inclusive, were .132 inch wire (10 gage) of approximately the following analysis (ordinary low carbon stock):

C=.05% max.; Mn=.20% max.; S=.030% max.; P=.025% max.; Fe=balance (by difference).

Specimens Nos. 7-9, inclusive, were .132 inch wire (10 gage) of approximately the following analysis (ordinary copper-silicon stock):

C=.06-.11%; Mn=.30-.45%; S=.040% max.; P=.025% max.; Si=.08-.15%; Cu=.20% min.; Fe=balance (by difference).

Annealing temperatures, all wires, °F. 1800 to 1940

Pickling acid concentration, all wires per cent. 10.3 to 11.3

No flux on any specimen.

As was mentioned above, the correct preheater temperatures are ascertainable with difficulty as a matter of predetermination. It is simpler to adjust the preheater setting during the coating operation to give the results sought. This is shown by the illustrated graph which clearly establishes the relationship between the temperatures of the wire and the fused bath. The curves are based upon observations made of the coating of .132 inch diameter wire (10 gage) similar to those set forth in the preceding table, and the temperatures referred to are those of the wire just as it is about to be immersed—not temperatures at the preheater. From this graph, an approximation of what the preheater setting must be to produce a coating of given weight, for a given bath temperature, may be had.

As soon as the coating is cast on the wire, which is estimated to take place in one-half second or less, the alloying action between the iron and the zinc begins with the formation of intermetallic compounds, possibly FeZn₁₀ and FeZn₇, in progressive succession. This action will continue slowly until the coated wire leaving the bath has cooled to approximately 200 degrees centigrade (392 degrees Fahrenheit), at which temperature the action is practically arrested. Ordinarily, the object is to cast on as much pure zinc as possible, while forming the smallest amount of alloy layer that is compatible with the acquisition of good bond between the base and coating metals.

After coating, the wire may travel in still air 20 to 30 feet, depending on the size of the wire, before its temperature is reduced to 200 degrees centigrade. At the speed of travel of the wire,

the wire through a cooled tube, or through a water quench to arrest the diffusion of the iron to the zinc. This manner of casting a zinc coating on an iron base, and quickly cooling the coated wire to prevent the formation of a thick iron-zinc alloy layer, leaves an outer coating of crystallized zinc which should be worked (as by drawing a wire through a die if containing more than three ounces of coating) in order that the coated article may stand the commercial button test or its equivalent.

From the foregoing, it will be seen that the present invention provides ways and means for maintaining constant conditions, as to all factors entering into the coating operation which affect the thickness of the coating, and for controlling the end result with great exactitude. Aside from the precision afforded, other advantages accrue to the use of the present invention in coating operations; for instance, the coating metal is preserved and not wasted; the reservoir of coating metal can be much smaller and the temperature of the fused bath much lower. This, in the case of zinc, obviates the maintenance of large quantities of zinc at high temperatures with the resultant high dross losses thus usually encountered. The invention also eliminates dross forming from the use of flux, since in practice the present invention does not necessarily require the use of a flux.

Though not specifically mentioned hereinbefore, it is to be understood that the present invention is also applicable for coating wire, the surface of which has been prepared so that, although the coating metal will cast thereon, it will not bond therewith, even though ordinarily there would be solubility between the coating and coated substances. This may be illustrated as follows: An iron wire is first cleaned in nitric acid and the surface becomes passivated. This will hinder the formation of a chemical bond, and, yet, by applying the chilling potential of the wire to cast coating therearound, a coating may be acquired which may be tightly fixed to the wire; particularly, where working of the coating, and/or the base metal, such as, by passing the wire through the die, is subsequently effected.

Again, if an iron wire is subjected to anodic oxidation, a finely divided and very evenly dispersed oxide coating may be formed on its surface. This oxide coating can be very closely controlled in its formation, and, afterwards, the wire may be severely bent without the coating cracking. A wire prepared in this manner may be fur-

ther prepared by drying in a preheater in accordance with the teachings hereinbefore set forth and then passed through a bath of coating metal. The oxide coating, as in the case of iron and zinc, will prevent the formation of a chemical bond. This is illustrated by specimen No. 9 in the foregoing table, which was preheated in air, and which, though acquiring a heavy cast coating, failed to show any alloy between its base and coating metals. The coating will resemble a cast pipe or sleeve which has been shrunk upon the wire, and this may be worked hot or cold, as by drawing the coated wire through a die, to augment the physical bond between the coating and coated metal.

Still another alternative contemplates that a ferrous wire be copper plated, which is commonly referred to by the trade as "liquor finished" wire, and then subjected to the coating processes herein outlined. In the case of zinc, the coating metal is cast on the copper coated iron wire, and the copper will alloy with the zinc. The copper, in the first place, will have formed a molecular bond with the iron, and, the copper and zinc will go into solid solution to form a physico-chemical bond.

This application is a division of my copending application entitled "Metal coating," bearing Serial No. 280,895 and filed June 23, 1939.

I claim:

1. Wire coating apparatus comprising a bath of molten metal; a tube passing into said metal and terminating upwardly at a point beneath the surface of said bath; and means for causing a wire to pass through said bath and tube; there being means for preventing entry of molten metal into said tube at its submerged terminus.

2. Wire coating apparatus comprising a bath of molten metal; a tube passing into said metal and terminating upwardly at a point beneath the surface of said bath; and means for causing a wire to pass at substantially constant speed through said bath and tube; there being means for preventing entry of molten metal into said tube at its submerged terminus.

3. Apparatus as in claim 2, including means for adjusting the depth of the submerged end of said tube beneath the surface of said bath.

4. Wire coating apparatus comprising a bath of molten metal; a tube passing into said metal and terminating upwardly at a point beneath the surface of said bath; means for introducing a stream of gas into said tube; and means for causing a wire to pass through said bath and tube; there being means for preventing entry of molten metal into said tube at its submerged terminus.

5. Wire coating apparatus comprising a bath of molten metal; a tube passing into said metal and terminating upwardly at a point beneath the surface of said bath; means for causing a wire

to pass through said bath and tube; and a heat and wear resisting packing between said wire and tube at the submerged end of said tube to prevent entry of molten metal into said tube.

6. Apparatus as in claim 5 in which said packing consists of a member of the group, tantalum carbide, tungsten and tungsten carbide.

7. Wire coating apparatus comprising a bath of molten metal; a tube passing into said metal and terminating at a point beneath the surface of said bath; means for causing a wire to pass through said bath and tube; a packing member, composed of material from the group tantalum carbide, tungsten, and tungsten carbide, substantially closing the submerged end of said tube; there being an opening through said packing member substantially conforming to the cross section of said wire, and permitting free passage of said wire, while preventing entry of molten metal into said tube through said opening around said wire.

8. Wire coating apparatus comprising a bath of molten metal; a tube partly outside of said bath, extending into said bath, and terminating upwardly at a point beneath the surface of said bath; means for causing a wire to pass through said tube, out the submerged end thereof, and out through the surface of said bath; there being means for preventing entry of molten metal into said tube at its submerged end; means for holding a substantially constant temperature in said tube; and means for closely regulating the temperature of said bath.

9. Wire coating apparatus comprising a bath of molten metal; a tube partly outside of said bath, extending into said bath, and terminating upwardly at a point beneath the surface of said bath; means for causing a wire to pass through said tube, out the submerged end thereof, and out through the surface of said bath; there being means for preventing entry of molten metal into said tube at its submerged end; means for passing gas into said tube; means for holding a substantially constant temperature in said tube; and means for closely regulating the temperature of said bath.

10. Wire coating apparatus comprising a bath of molten metal; a tube partly outside of said bath, extending into said bath, and terminating upwardly at a point beneath the surface of said bath; means for causing a wire to pass at a substantially constant speed through said tube, out the submerged end thereof, and out through the surface of said bath; there being means for preventing entry of molten metal into said tube at its submerged end; means for holding a substantially constant temperature in said tube; and means for closely regulating the temperature of said bath.

ARCH W. HARRIS.