March 1, 1949. J. S. NACHTMAN 2,463,412

ELECTRIC RESISTANCE HEAT-TREATING OF ELECTROPLATED COATINGS

Filed July 25, 1942 2 Sheets-Sheet 1

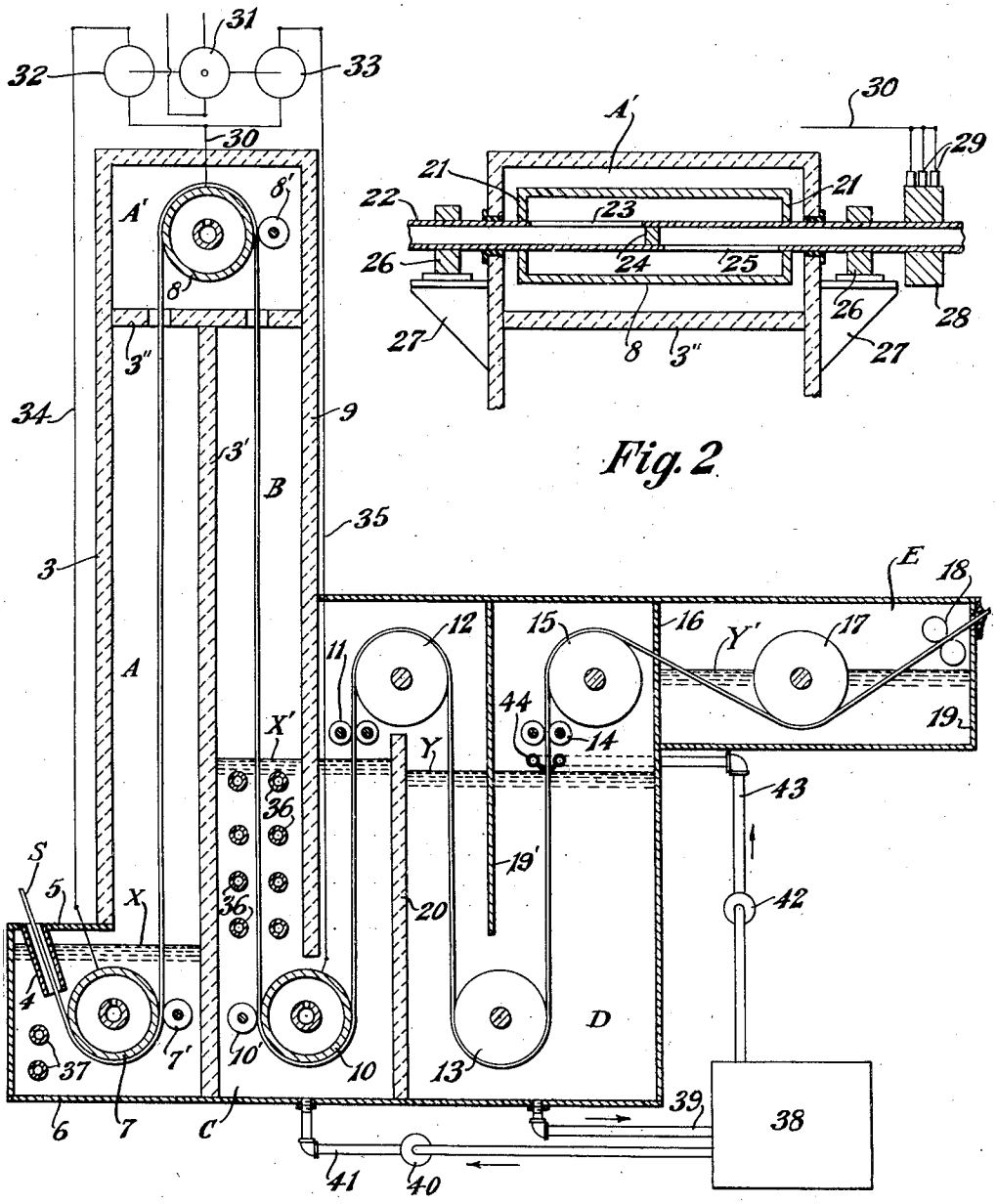


Fig. 1

Fig. 2

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2 Sheets-Sheet 2

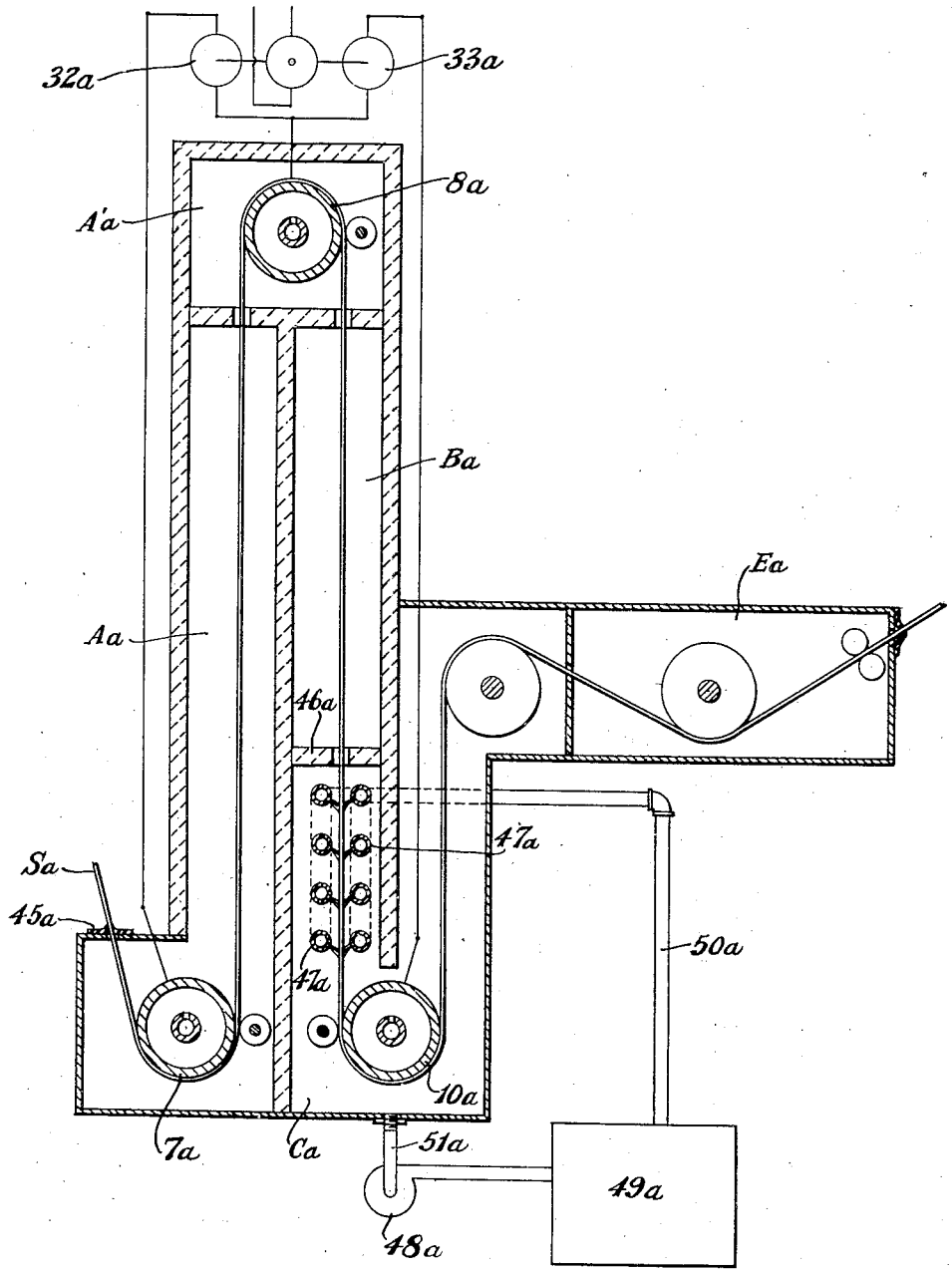


Fig. 3

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2,463,412

ELECTRIC RESISTANCE HEAT-TREATING OF ELECTROPLATED COATINGS

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4 Claims. (Cl. 204—36)

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The invention relates generally to the heat treatment of electroplated coatings on the surface of metallic strip, sheet, wire and other articles, and more particularly to the heat treatment of electroplated coatings of tin, or tin or other low melting point metals alternating with layers of other metals, by passing an electric current through the base stock.

Where the electroplated coating is tin only, the purpose of the heat treatment is to brighten the coating. Where the electroplated coating consists of multiple layers of metals including tin or other low melting point metals, the purpose of the heat treatment is to effect at least a partial alloying of the electroplated layers.

The present invention will be described as applied to the heat treatment of strip metal having an electroplated coating of tin to brighten the tin for producing tin plated strip suitable for making food product containers. It is to be understood that the heat treatment of multiple layer coatings will be similar, although the time and temperature conditions may be suitably varied.

In my prior Patent No. 2,266,330, issued December 16, 1941, I disclose the use of contact rolls for passing an electric current through a tin plated steel strip to preheat the strip to a temperature below the melting point of the coating, after which the preheated strip is passed through reducing rolls heated above the melting point of the coating to melt and smooth the coating. However, such a contact roll arrangement cannot be used for electrically heating the strip above the melting temperature of the coating because the contact rolls will damage the molten coating.

It is a general object of the present invention to provide a novel method for heat treating a strip electroplated with tin or multiple layer of metals including tin or other low melting point metals, by passing an electric current through the strip.

Another and more specific object is to provide a novel method of brightening tin or alloy electroplated strip by passing an electric current through the strip to raise its temperature above the melting point of tin or above the melting point of the lowest melting point metal in the coating, without contacting the molten coating or damaging the coating in any way.

Another object is to provide a novel method of heat treating electroplated strip continuously by passing an electric current through the strip.

These and other objects are accomplished by the novel methods and apparatus comprising the present invention, which is hereinafter described

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in detail with reference to the accompanying drawings forming part hereof, and which is defined in the appended claims.

In heat treating a strip electroplated with tin in accordance with the present invention, the strip is electric resistance heated rapidly and uniformly in a non-oxidizing medium to a temperature above the melting point of tin for a short time to melt the coating, and then the strip is rapidly cooled or quenched in a non-oxidizing preferably hydrocarbon medium, without physically contacting anything else, to a temperature below the solidification point of tin.

Referring to the drawings in which preferred embodiments of apparatus for carrying out the invention are shown by way of example,

Figure 1 is a diagrammatic longitudinal sectional view of one form of apparatus;

Fig. 2 is a transverse sectional view of the upper roll thereof; and

Fig. 3 is a view similar to Fig. 1 of a modified form of apparatus.

Similar numerals refer to similar parts throughout the drawings.

Referring first to Figs. 1 and 2, the strip S, which has been previously electroplated with tin and rinsed and dried, is shown entering the apparatus through a tube 4 which extends below the surface of the liquid medium X in the lower part of compartment A of the apparatus, and tube 4 forms a seal around the strip entering the compartment. The strip is propelled through the apparatus by suitable means (not shown).

It may be desirable to subject the tin plated strip to an acid wash after electroplating, in order to remove the whitish film sometimes remaining on the surface of the tin coating, because this film may cause fogging of the mirror finish obtained by the subsequent brightening treatment. Suitable acid washes for this purpose are disclosed in my prior Patent No. 2,330.609 dated September 28, 1943, and entitled Brightening procedure.

The compartment A of the apparatus formed by vertical walls 3 and 3' is the preheating compartment and its lower end is enlarged by laterally extending walls 5 and 6 for containing the liquid medium X in which a lower contact roll 7 is immersed. The strip S passes downwardly under roll 7 and then vertically upward through preheating compartment A and through a horizontal partition wall 3'' into a top compartment A' in which a top contact roll 8 is journaled. The strip passes over contact roll 8 and then vertically downward through a fusing compartment B

formed by vertical walls 3' and 9 and thence into a cooling or quenching compartment C which is filled with a non-oxidizing liquid preferably hydrocarbon medium indicated at X'. A contact roll 10 is journaled in the lower portion of compartment C and the strip passes under roll 10 and then vertically upward through a pair of squeegee rolls 11 and over a roll 12, thence vertically downward through another hydrocarbon medium indicated at Y in compartment D, under roll 13 in compartment D, then vertically upward through squeegee rolls 14 and over roll 15. From roll 15 the strip passes through partition wall 16 angularly downward through a hydrocarbon medium indicated at Y' and under roll 17 in compartment E, and thence through squeegee rolls 18 and wall 19 into the atmosphere.

In cooling compartment C the partition wall 9 depends into liquid X' so that the downcoming portion of the strip from fusing compartment B is on one side of the wall 9, while the portion of the strip going from roll 10 to roll 12 is on the other side. Similarly, compartment D has a partition wall 19' depending into liquid Y between the portions of the strip entering and leaving compartment D. Compartment C is separated from compartment D by a partition wall 20.

The contact rolls 7, 8 and 10 perform the dual function of guiding the strip S through the apparatus and of transmitting electric current to the moving strip. Preferably the contact rolls 7, 8 and 10 have associated with them pressure rolls 7', 8' and 10' respectively, for keeping the strip in close contact with the contact rolls. The construction of and the electrical connections to rolls 7, 8 and 10 are substantially identical, so that the description of contact roll 8 as shown in transverse section in Fig. 2 will apply to contact rolls 7 and 10. Rolls 7, 8 and 10 are preferably made of a good conducting material such as copper with a hard polished surface such as chrome plate on their outer surfaces.

Referring to Fig. 2, the roll 8 is preferably a hollow cylinder closed at both ends by end walls 21 through which is inserted a hollow shaft 22. One end of the hollow shaft 22 is connected with a source of cooling fluid which passes from the inside of the shaft through a slotted opening 23 at one side of the partition wall 24 into the roll 8 to cool the same. The cooling fluid is withdrawn from the roll 8 through the slotted opening 25 in the shaft on the other side of partition 24, and discharges out of the other end of the shaft.

While the contact rolls are shown and described as being internally cooled by way of example, it should be understood that they may be externally cooled without departing from the scope of the invention.

Preferably the shaft 22 is journaled in bearings 26 which are supported on brackets 27 welded or otherwise secured to the chamber walls, and at one side of the chamber, the lower shaft 22 has mounted thereon a current collecting drum 28 slidably engaged by the electric brushes 29 which are connected by a bus bar 30 to an electric generator later described herein.

Rolls 12, 13, 15 and 17 are strip guiding rolls only, and should be constructed of a material such as synthetic rubber which will not scratch or mar the plated surface of the strip.

Contact rolls 7, 8 and 10 are connected to a source of electric current such as the motor generator set shown in Fig. 1 consisting of a motor 31 and generators 32 and 33. One generator is

preferably connected between contact rolls 7 and 8 and the other generator is connected between contact rolls 8 and 10. For example, the bus bar 30 from contact roll 8 is connected to one terminal of generator 32 and the bus bar 34 from contact roll 7 is connected to the other terminal of generator 32. Likewise, bus bar 30 from contact roll 8 is connected to one terminal of generator 33 and bus bar 35 from contact roll 10 is connected to the other terminal generator 33. Generators 32 and 33 are provided with a conventional control, not shown, for controlling the current as desired.

The electric current from generator 32 is passed through the strip in the preheating compartment A at such a rate that the strip temperature as the strip passes over contact roll 8 will be mainained at approximately 440° F., which is slightly below the melting point of the tin coating on the strip. The electric current from generator 33 is passed through the strip in the fusing compartment B at such a rate that the strip temperature will be above the melting point of tin (449.5° F.) before the strip reaches the surface of the liquid X'.

It is to be understood that more than two contact rolls may be used contacting the strip preceding the zone or location where the tin coating on the strip fuses. Such additional rolls may be necessary to prevent burning of the strip due to the passage of high currents, or for the purpose of bringing the temperature of the strip to the desired temperature more rapidly.

The liquid X' is cooled preferably by a series of cooling pipes 36 located on opposite sides of the strip, so that as the strip is submerged in the liquid X' its temperature is rapidly lowered to below the solidification point of the tin coating, that is 425° F. or less, before the strip contacts roll 10. Preferably, the temperature of liquid X' is maintained at a sufficiently low temperature to solidify the tin quickly and thereby prevent spangles in the tin surface.

Liquid X' must be a non-oxidizing medium which has exceptionally good heat transfer properties so as to insure cooling of the strip below solidification point of the tin before the strip reaches roll 10 because that portion of the strip submerged in liquid X' and approaching roll 10 is heated by the electric current from generator 33. I have found by experiment that a number of hydrocarbons having boiling ranges within the range of 450° F. to 850° F. are satisfactory for use as the liquid X'. Suitable hydrocarbons having these desired properties include aliphatic and aromatic hydrocarbons such as certain alkanes, olefins, petroleum and coal tar solvents, and oils; such oils being stable at their operating temperatures and causing no discoloration or detrimental products of decomposition on the strip surface.

An example of a typical petroleum fraction or solvent having a boiling point range between 450° F. and 850° F., and suitable for use as liquid X, is a material sold under the trade name of "Mentor 28," which has a boiling point range of approximately 505° F. to 650° F., a flash point of approximately 255° F. and a fire point of approximately 294° F. This material has a viscosity of 483 centipoises at 25° C., has practically no vapor pressure or evaporation loss at 25° C. and a gravity range between 35° A. P. I. to 38° A. P. I.

Such gravity range indicates a thermal conductivity of .94 to .956 B. t. u. per hour per square foot per degree F. per inch at 100° F., as calcu-

lated from formulae of C. S. Cragoe, Bureau of Standards, Misc. Pub. 97 (1929).

The liquid X in the lower part of compartment A may be the same as liquid X', but liquid X can be another non-oxidizing medium which has a lower boiling range, because the liquid X is maintained at a temperature of about 200° F. by means of heating pipes **37**. The primary function of the liquid X is to maintain a seal for the compartment A and to prevent oxidation of the tin coating as the strip passes therethrough and through the preheating chamber A, the heating of the liquid X, causing vapors therefrom substantially to fill this chamber A, surrounding and in contact with the strip therein.

If it is found necessary in order to maintain a non-oxidizing atmosphere in compartments A, A' and B between liquids X and X', a non-oxidizing or reducing atmosphere as cracked ammonia, hydrogen, nitrogen or carbon dioxide may be introduced into the preheating and fusing chambers A and B. In this case the liquid seal X may or may not be required.

The liquid Y in compartment D should be a medium which will act as a solvent for the liquid X' which is carried over on the strip surface in compartment D. When "Mentor 28" is used as the liquid X' the liquid Y may be one of the hydrocarbons from the alkane group, such as pentane. Pentane is a low boiling hydrocarbon which is a solvent for "Mentor 28."

Liquid Y' in compartment E may also be pentane to which a small amount of vegetable oil, for example one-half per cent by weight of palm oil, has been added so that an imperceptible oil film will remain on the strip after the pentane has evaporated.

The film of liquid X' which has been carried by the strip into compartment D may be separated and returned to compartment C by a distillation unit indicated at **38**. The mixture of liquids X' and Y is conducted to unit **38** through pipe **39**, and liquid X' is returned to compartment C by means of a pump **40** through pipe **41**, while the liquid Y is returned to compartment D by means of a pump **42** through pipe **43** and sprays **44**.

In carrying out the method of the invention in the apparatus shown in Figs. 1 and 2, the strip in passing around contact roll **7** submerged in liquid X is heated to a temperature of about 200° F. by the time it leaves the liquid X because the liquid X is maintained at approximately that temperature. Between liquid X and contact roll **8** the strip temperature is raised to about 440° F. by passage of the electric current through the strip between rolls **7** and **8**. The temperature of the strip between contact roll **8** and the liquid X' must be raised to above the melting point of tin by passage of the electric current through the strip between contact rolls **8** and **10**, in order to melt and brighten the tin coating.

The cooling fluid is circulated through contact rolls **7**, **8**, and **10** at a temperature and rate of flow such to always maintain the contact rolls at a temperature below the melting point of tin. In the case of a multiple layer coating, the rolls are maintained at a temperature below the melting point of the lowest melting point metal or alloy formed in the coating.

The capacities of the electric generators **32** and **33** depend on at least two factors, namely, the speed of the strip and the size of the strip, or in other words the mass of steel strip being treated per unit of time. The voltage of the electric current supplied will be relatively low and will be selected in accordance with these factors.

For example, assuming the steel strip to have:

1 inch width
.010 inch thickness
.006 ohm resistance per foot length
.036 pound of weight per foot
.12 specific heat

Since the temperature rise in the preheat zone A is from 200° to 440° F., the heat required is $.036\times.12\times240=1.037$ B. t. u. Assuming heating time to be 3.6 seconds or .001 hr., the rate of heating will then be $1.037/.001=1037$ B. t. u. per hr.

$$1037/3412=.3 \text{ kw. h./hr.}$$

I^2R=watts $I^2=300/.006$ $I=226$ amperes

Assuming strip speed to be 200 F. P. M. or 3.33 F. P. S., the length of strip in preheat will be $3.33\times3.6=12$ feet. Voltage required is therefore $226\times.006\times12=16.1$ volts.

Assuming the strip temperature will rise 24° F. in the fusing zone, and that the fusing time and quenching time are equal each requiring 1.8 seconds, or a total of 3.6 seconds to fuse and then cool the strip sufficiently to permit the tin to be contacted by roll **10**; the length of strip in the fusing zone will be $3.33\times1.8=6$ feet. The length of strip in the cooling liquid above contact roll **10** will be 6 feet, making a total of 12 feet between the contact roll **8** and contact roll **10**.

The heat required is

$$.036\times.12\times24=.1037 \text{ B. t. u.}$$
$$=.03 \text{ kwh. hr.}$$

$I^2=30/.006$ $I=71$ amperes

and the voltage required for fusing will be $71\times.006\times12=5.1$ volts.

Therefore the generator used will depend upon the particular set up of strip speed and size of strip.

The modified form of apparatus shown in Fig. 3 is generally similar to the apparatus of Fig. 1 in that it includes a preheating compartment A*a*, top roll compartment A'*a*, fusing compartment B*a*, and cooling compartment C*a*. The compartment corresponding to compartment D in Fig. 1 is omitted and compartment E*a* may contain a liquid hydrocarbon medium with a small percentage of vegetable oil to leave an interceptible oil film on the strip after it passes into the atmosphere.

The strip S*a* passes through a flexible seal **45***a* into the lower part of the preheat compartment A*a* under a contact roll **7***a*, then upward through the preheating compartment A*a* and over a contact roll **8***a*, from which it passes vertically downward through the fusing compartment B*a*. Preferably a partition wall **46***a* is provided between the fusing compartment B*a* and the cooling compartment C*a*. In the cooling compartment a series of sprays **47***a* are located on opposite sides of the strip for spraying the vapor of a low boiling non-oxidizing hydrocarbon medium against the strip to quickly cool the same below the solidification point of the tin. This hydrocarbon vapor is preferably selected from the aliphatic and aromatic hydrocarbons having a boiling range below the melting point of tin, and may for example be pentane which boils at 97° F. The pentane may be circulated by means of a fan **48***a* from a cooler **49***a* at about 100° F. through a pipe **50***a* to the sprays **47***a*, and hot pentane vapor is returned to

the fan 48*a* from compartment C*a* through the pipe 51*a*.

The pentane vapor from the sprays 47*a* will fill the compartments B*a*, A'*a* and A*a* so as to maintain a non-oxidizing atmosphere throughout all of those compartments, and accordingly it is not necessary to provide a liquid seal where the strip enters the lower part of the preheating compartment A*a*.

The contact rolls 7*a* and 8*a* are connected to the terminals of electric generator 32*a* and the contact rolls 8*a* and 10*a* are connected to the terminals of electric generator 33*a* in a manner similar to that shown in Fig. 1, and the internal cooling of the contact rolls is accomplished in the same way as shown and described in connection with the contact rolls in Fig. 1.

The method as carried out in the apparatus shown in Figs. 1 and 3 may be modified in other ways without departing from the scope of the invention as defined in the claims. For example, cooled liquid pentane may be introduced into compartment C as the liquid X', and the non-oxidizing vapors from the pentane will fill the fusing and preheat chambers so that the liquid seal X may be omitted.

The novel method of heat treating electroplated strip provides for electric resistance heat treating the strip continuously to brighten or alloy the coating without damaging the coating in any way.

I claim:

1. In a method of heat treating an electrotin plated strip, the steps of continuously passing the strip through respective preheating and fusion zones under non-oxidizing conditions, preheating the strip in the preheating zone to a temperature close to but below the melting point of the tin by passing an electric current through said strip while a portion of the strip in the preheating zone is subjected to a hot fluid whereby the electric heat applied to said portion of the strip in the preheating zone is not dissipated therein, applying a source of heat to the fluid separate from the electric heating of the strip, and thereafter heating the strip in the fusion zone during passage therethrough.

2. In a method of heat treating an electro-tin plated strip, the steps of continuously passing the strip through respective preheating and fusion zones under non-oxidizing conditions and through a hot fluid in at least one of said zones, preheating the strip in the preheating zone to a temperature close to but below the melting point of the tin by passing an electric current through said strip while a portion of the strip in the preheating zone is subjected to the hot fluid and the strip is surrounded by a hot fluid in contact with the strip and confined within a chamber including the preheating zone and while said portion of the strip in the preheating zone is electrically heated, applying a source of heat to the fluid separate from the electric heating of the strip, thereafter heating the strip to a fusion temperature of the tin in the fusion zone during passage therethrough, and thereafter passing the strip into a quenching zone containing a liquid bath.

3. In a method of heat treating an electro-tin plated strip, the steps of continuously passing the strip through respective preheating and fusion zones under non-oxidizing conditions and through a hot fluid in at least one of said zones, preheating the strip in the preheating zone to a temperature close to but below the melting point of the tin by passing an electric current through said strip while a portion of the strip in the preheating zone is subjected to the hot fluid and the strip is surrounded by a hot fluid in contact with the strip and confined within a chamber including the preheating zone and while said portion of the strip in the preheating zone is electrically heated by passing an electric current through said portion of the strip, applying a source of heat to the fluid separate from the electric heating of the strip, and thereafter heating the strip to a fusion temperature of the tin in the fusion zone during passage therethrough, and thereafter passing the strip into a quenching zone containing a liquid bath having a thermal conductivity of at least .94 B. t. u. per square foot per inch per degree F. per hour at 100° F.

4. In a method of heat treating an electro-tin plated strip, the steps of continuously passing the strip through respective preheating and fusion zones under non-oxidizing conditions and through a hot fluid in at least one of said zones, preheating the strip in the preheating zone to a temperature close to but below the melting point of the tin by passing an electric current through said strip while a portion of the strip in the preheating zone is subjected to the hot fluid and the strip is surounded by a hot fluid in contact with the strip throughout a substantial portion of the preheating zone and while electrically heated, applying a source of heat to the fluid separate from the electric heating of the strip, thereafter heating the strip to a fusion temperature of the tin in the fusion zone during passage therethrough by passing a different electric current through this portion of the plated strip between points of connection with the strip spaced lengthwise of the strip on opposite sides of the fusion zone, and thereafter passing the strip into a quenching zone containing a liquid bath.

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