

April 19, 1966 **J. R. SPRAUL ETAL** **3,247,013**
SIMULTANEOUSLY NICKEL COATING THE INTERIOR OF A METAL VESSEL
AND THE EXTERIOR OF METAL TUBES WITHIN THE VESSEL
Filed June 30, 1961 3 Sheets-Sheet 1

3,247,013

AND THE EXTERIOR OF METAL TUBES WITHIN THE VESSEL

3 Sheets-Sheet 1

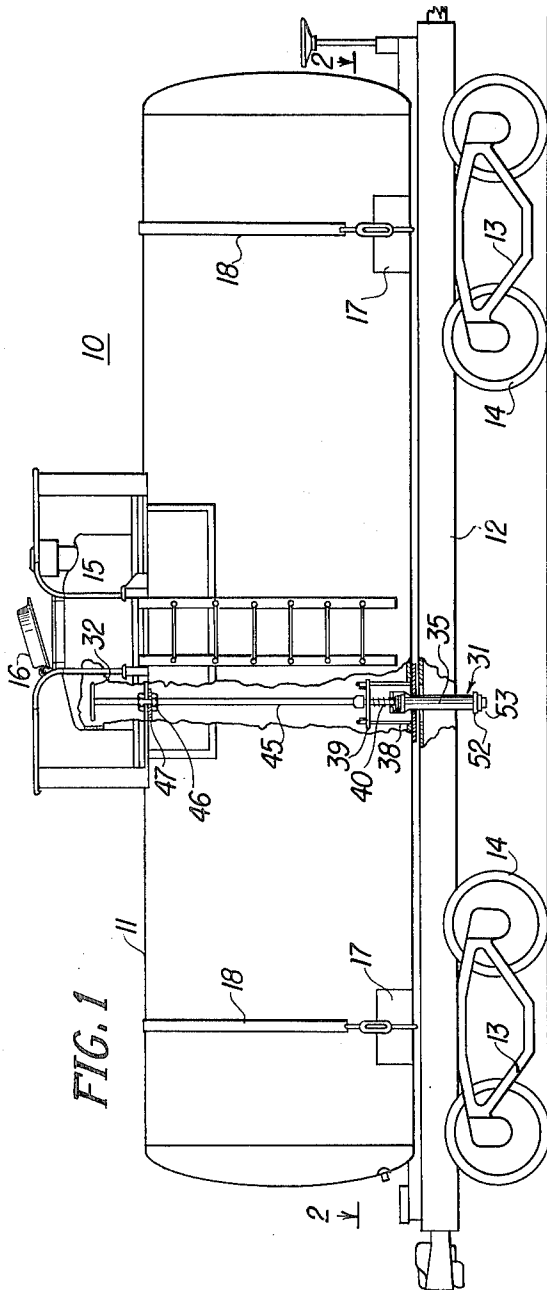


FIG. 1

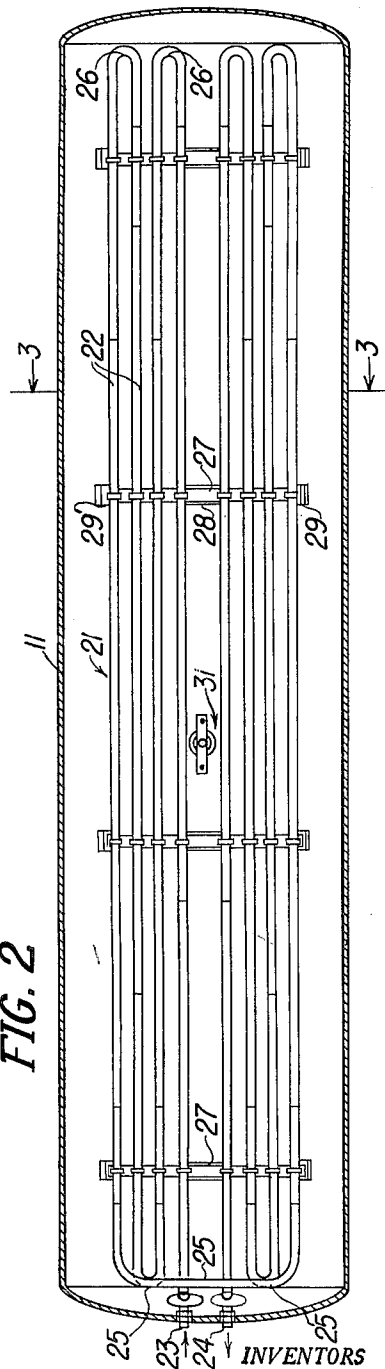


FIG. 2

INVENTORS

Joseph R. Spraul

BY *Donald E. Metheny*

Pringle, Baird Clayton, Miller
& Vogel, Attys.

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3 Sheets-Sheet 2

FIG. 3

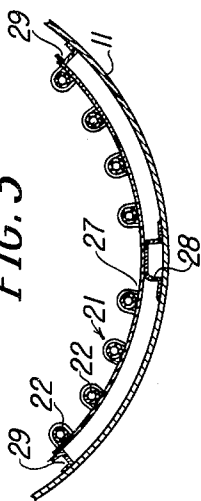


FIG. 5

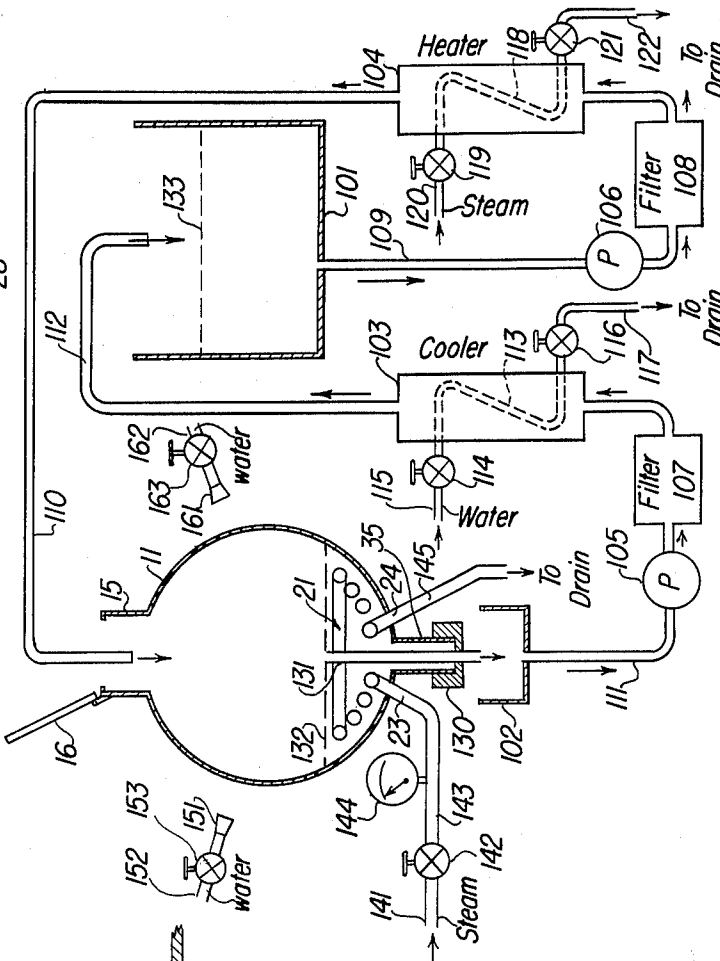
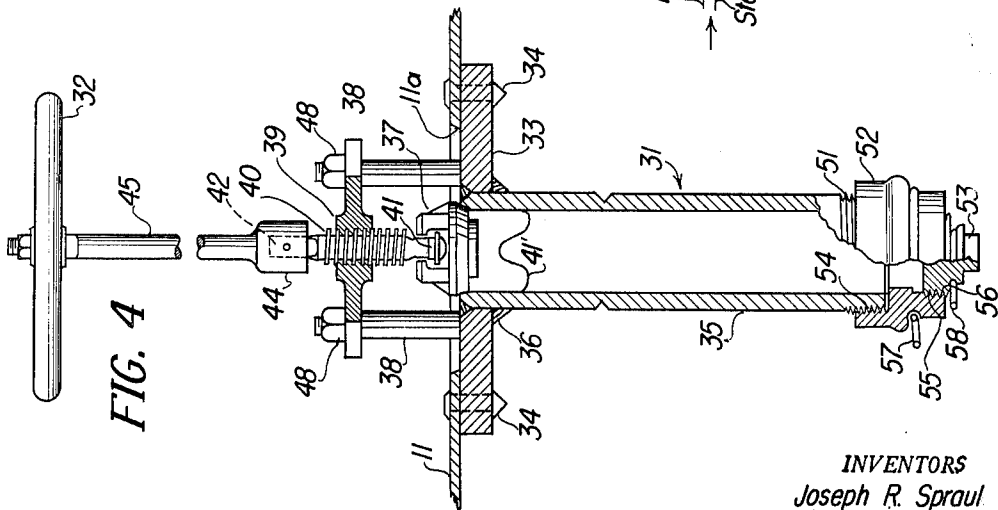


FIG. 4



April 19, 1966

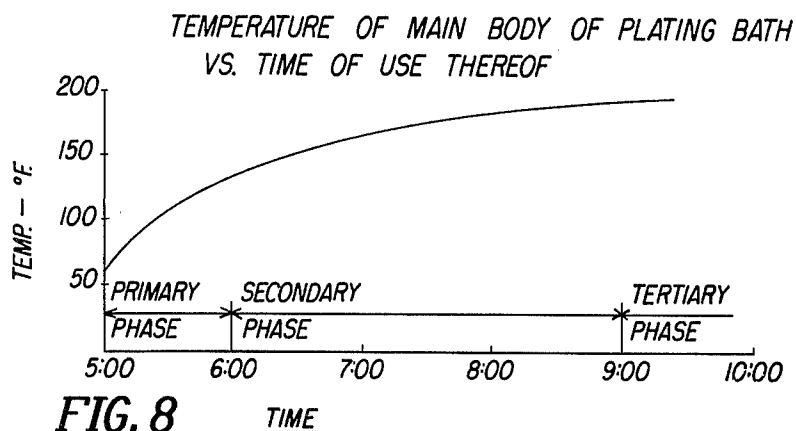
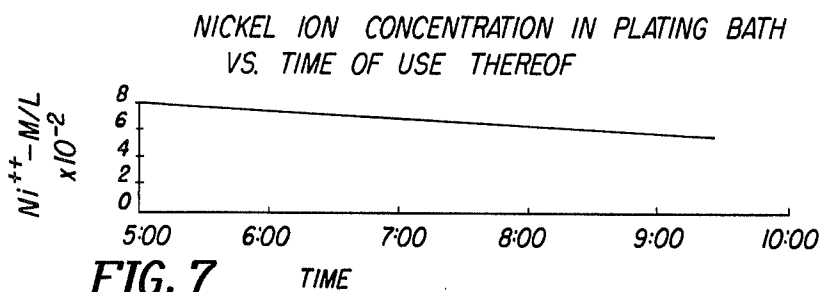
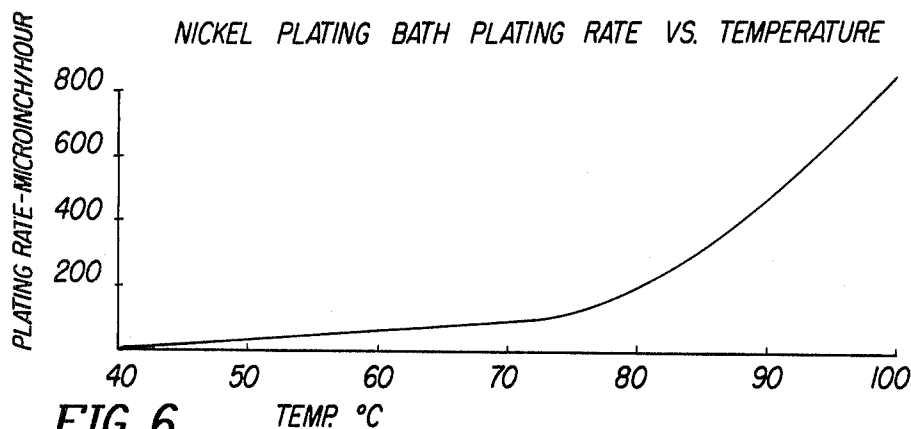
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INVENTORS

Joseph R. Spraul

BY Donald E. Metheny

Prangle, Baird, Clayton,
Miller & Vogel Attys.

1

2

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SIMULTANEOUSLY NICKEL COATING THE INTERIOR OF A METAL VESSEL AND THE EXTERIOR OF METAL TUBES WITHIN THE VESSEL

Joseph R. Spraul, Palos Verdes Estates, Calif., and Donald E. Metheny, Highland, Ind., assignors to General American Transportation Corporation, Chicago, Ill., a corporation of New York

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2 Claims. (Cl. 117-97)

The present invention relates to methods of depositing metal from metal plating baths of the aqueous chemical reduction type.

It is a general object of the invention to provide an improved and simplified method of coating with metal a workpiece from a metal plating bath of the type noted, wherein the main body of the plating bath in which the workpiece is immersed is maintained at a relatively low temperature at which the plating bath is characterized by maximum stability and a low plating rate, and wherein only a thin layer of the plating bath disposed in contact with the surface of the workpiece is maintained at a relatively high temperature at which the plating bath is characterized by minimum stability and a high plating rate, and wherein the main body of the plating bath is maintained at the relatively low temperature mentioned by cooling the same.

Another further object of the invention is to provide an improved method of simultaneously coating with metal the surfaces of first and second workpieces and utilizing an aqueous chemical reduction type metal plating bath, wherein the first and second workpieces are immersed in the plating bath, wherein the surface of the first workpiece is heated while it is immersed in the plating bath so as to maintain a first thin layer of the plating bath disposed in contact with the surface of the first workpiece at a relatively high temperature at which the plating bath is characterized by a high plating rate, and wherein the surface of the second workpiece is cooled while it is immersed in the plating bath so as to maintain a second thin layer of the plating bath disposed in contact with the surface of the second workpiece at a relatively low temperature in which the plating bath is characterized by a low plating rate, whereby during a given time interval of immersion of the first and second workpieces in the plating bath, a relatively thick metal coating is plated upon the surface of the first workpiece and a relatively thin metal coating is plated upon the surface of the second workpiece.

A further object of the invention is to provide a nickel coating method of the character described, utilizing any one of the large number of plating baths of the nickel cation-hypophosphite anion type and having a boiling point somewhat above 100° C. and characterized by minimum stability and a high plating rate at a temperature within the given range 88° C. to 98° C., and by maximum stability and a low plating rate at a temperature below the given range noted.

A still further object of the invention is to provide a nickel coating method of the character described that is well-suited to simultaneous coating of the exterior surface of a steel heating coil and the bottom interior surface of a steel tank body for a railway tank car, wherein the heating coil is disposed in the lower portion of the tank body, wherein a plating bath of the nickel cation-hypophosphite anion type is held in the lower portion of the tank body in submerging relation with the lower interior surface thereof and with the exterior surface of the heating coil, wherein steam is passed through the heating coil while it is submerged in the plating bath so as to heat the exterior surface thereof in order to maintain a first

thin layer of the plating bath disposed in contact with the exterior surface of the heating coil at a relatively high temperature, and wherein water is sprayed upon the tank body while the interior surface thereof is submerged in the plating bath so as to cool the interior surface thereof in order to maintain a second thin layer of the plating bath disposed in contact with the lower interior surface of the tank body at a relatively low temperature, whereby during a given time interval a relatively thick coating of nickel is plated upon the exterior surface of the heating coil and a relatively thin coating of nickel is plated upon the lower interior surface of the tank body.

Further features of the invention pertain to the particular arrangements of the steps of the method; whereby the above-outlined and additional operating features thereof are attained.

The invention, both as to its organization and method of operation, together with further objects and advantages thereof will best be understood by reference to the following specification, taken in connection with the accompanying drawings, in which:

FIGURE 1 is a side elevational view, partially broken away, of a railway tank car including a tank body in which there is arranged a heating coil, which assembly is plated in accordance with the method of the present invention;

FIG. 2 is an enlarged horizontal sectional view, taken through the lower portion of the tank body, and illustrating the disposition of the heating coil arranged therein, this view being taken along the line 2—2 in FIG. 1;

FIG. 3 is a further enlarged fragmentary vertical sectional view, taken through the bottom of the tank body, this view being taken in the direction of the arrows along the line 3—3 in FIG. 2;

FIG. 4 is a greatly enlarged fragmentary side elevational view, partly in section, of the outlet valve mechanism that is incorporated in the tank body;

FIG. 5 is a schematic diagram of the apparatus incorporated in the system for coating the lower interior surface of the tank body and the exterior surface of the heating coil arranged in the lower portion of the tank body;

FIG. 6 is a graph illustrating the relationship between the plating rate and the temperature of a chemical nickel plating bath of the character of that employed in the present method;

FIG. 7 is a graph illustrating the relationship between the nickel ion concentration in the plating bath and the time of use thereof in the system of FIG. 5; and

FIG. 8 is a graph illustrating the relationship between the temperature of the main body of the plating bath and the time of use thereof in the system of FIG. 5.

Before proceeding with the description of the coating method of the present invention, it is advantageous to consider the general construction and arrangement of a typical railway tank car in which the present method is carried out for the purpose of coating with nickel the lower interior surface of the tank body and the exterior surface of the heating coil arranged in the lower portion of the tank body.

Referring to FIGS. 1 to 4, inclusive, of the drawings, there is illustrated a typical railway tank car 10 comprising a tank body 11 that is carried by a rigid underframe 12 that is supported adjacent to the opposite ends thereof by a pair of trucks 13 provided with track wheels. The tank body 11 is of elongated tubular form, and the top central portion thereof is provided with an upstanding dome 15 having a hatch opening in the top thereof that is provided with a hinged hatch cover 16 that is selectively movable between open and closed positions with respect to the cooperating hatch opening. The tank body 11 is directly supported upon a pair of longitudinally spaced-

3

apart saddle structures 17 carried by the top of the under-frame 12 adjacent to the opposite ends thereof and is removably retained in place by a pair of bands 18 cooperating with the saddles 17 and with the adjacent upper end portions of the tank body 11.

Arranged within the lower portion of the tank body 11 is a heating coil 21 that comprises, as illustrated, eight longitudinally extending and arcuately spaced-apart reaches 22, four of the reaches 22 being disposed on each side of the longitudinal vertical center plane of the tank body 11, as best shown in FIG. 2. At one end of the tank body 11, one of the lower reaches is provided with an inlet fixture 23 extending to the exterior and another of the lower reaches 22 is provided with an outlet fixture 24 extending to the exterior, which fixtures 23 and 24 are threaded to receive cooperating conduits for a purpose more fully explained herein. Certain ends of other of the reaches 22 disposed at the one end of the tank body 11 are connected together by suitable return bends 25 and the ends of the adjacent ones of the reaches 22 disposed at the other end of the tank body 11 are connected together by suitable return bends 26; whereby the eight reaches 22 in the composite heating coil 21 are connected together in series relation between the inlet fixture 23 and the outlet fixture 24.

The composite heating coil 21 is supported somewhat above the bottom wall of the tank body 11 by four longitudinally spaced-apart substantially arcuate-shaped brackets 27, as best shown in FIGS. 2 and 3; and each of the brackets 27 is supported adjacent to the central portion thereof by an associated foot 28 and supported adjacent to the opposite ends thereof by a pair of associated feet 29. In the arrangement, the feet 28 and 29 are disposed in arcuate spaced-apart relation and rigidly secured to the adjacent portions of the tank body 11, as by welding; and, in turn, the central portion of the bracket 27 is suitably secured to the feet 28 and the opposite ends of the bracket 27 are suitably secured to the respectively associated feet 29. Accordingly, the composite heating unit 21 is rigidly secured in place in the lower portion of the tank body 11 and in spaced relation with respect to the adjacent bottom wall of the tank body 11 so as to prevent rattling of the composite heating unit 21 when the railway tank car 10 is in use and so as to accommodate free circulation of the lading contained in the tank body 11 through the composite heating coil 21.

Also, the central bottom portion of the tank body 11 is provided with outlet valve mechanism 31 disposed below the dome 15 and selectively operative by a hand-wheel 32 arranged within the dome 15 and accessible from the exterior through the hatch opening when the associated hatch cover 16 occupies its open position. More particularly, as best shown in FIG. 4, an opening 11a is provided in the central bottom portion of the tank body 11 that is covered by an associated exterior valve plate 33, the valve plate 33 being suitably secured in place by a series of rivets, as indicated at 34. The central portion of the valve plate 34 carries a depending tube 35 that is provided in the upper end thereof with a valve seat 36 with which there cooperates a valve element 37. Also, the valve plate 33 carries two upstanding posts 38 that, in turn, carry a bridging plate 39 having a centrally disposed threaded opening therein positioned above the valve seat 36. Arranged in threaded engagement with the opening provided in the bridging plate 39 is a threaded element 40 that is provided with an enlarged head 41 suitably rotatably secured in place in a cavity provided in the top of the valve element 37; which arrangement accommodates ready rotation between the valve element 37 and the threaded element 40.

In view of the foregoing description, it will be understood that when the threaded element 40 is rotated in one direction (the clockwise direction as viewed from the upper end thereof), the same is moved downwardly with respect to the bridging plate 39 by virtue of the co-

4

operating threads therebetween; whereby the head 41 rotates with respect to the valve element 37 forcing the valve element 37 downwardly into firm closed position with respect to the valve seat 36 provided in the top end of the tube 35; whereby the outlet valve mechanism 31 is actuated into its closed position. On the other hand, when the threaded element 40 is rotated in the other direction (the counterclockwise direction as viewed from the upper end thereof), the same is moved upwardly with respect to the bridging plate 39 by virtue of the cooperating threads therebetween; whereby the head 41 rotates with respect to the valve element 37 forcing the valve element 37 upwardly into open position with respect to the valve seat 36 provided in the top end of the tube 35; whereby the outlet valve mechanism 31 is actuated into its open position.

The lower end of the valve element 37 carries guide structure 41 arranged within the upper end of the tube 35 for the purpose of guiding the same in its vertical movements with respect to the valve seat 36; and the extreme upper end of the threaded element 40 is squared, as indicated at 42, so that it may receive a cooperating squared socket 44 provided on the lower end of an upstanding valve stem 45, the extreme upper end of the valve stem 45 carrying the rotatable handle 32 arranged within the dome 15, as previously explained. Also, it is noted that the upper portion of the valve stem 45 is rotatably mounted in a suitable bearing 46 that is carried by a bracket 47 arranged adjacent to the bottom of the dome 15 and suitably secured to the adjacent top portion of the tank body 11; all as shown in FIG. 1. Thus it will be understood that the valve element 37 may be readily actuated between its open and closed positions with respect to the associated valve seat 36 through the valve stem 45 by manipulation of the valve wheel 32 arranged in the dome 15 when the hatch cover 16 occupies its open position with respect to the associated hatch opening.

Further, it is pointed out that the assembly comprising the valve element 37, the bridging plate 39 and the threaded element 40 may be removed upwardly from its normally supported position upon the ends of the posts 38, when the associated nuts 48 carried on the upper ends of the posts 39 are removed; whereby this assembly may be then removed from the interior of the tank body 11 through the hatch opening with the hatch cover 16 in its open position. Also, the valve stem 45 and the associated valve wheel 32 may be removed from the interior of the tank body 11 through the hatch opening when the hatch cover 16 occupies its open position.

The extreme lower end of the tube 35 is threaded, as indicated at 51, and carries a removable cap 52; which removable cap 52 carries a removable plug 53. More particularly, the upper end of the cap 52 is internally threaded, as indicated at 54, so that it may be readily placed and removed with respect to the thread 51 carried by the extreme lower end of the tube 35; and the lower end of the cap 52 is internally threaded, as indicated at 55, so that it may readily receive the external threads 56 carried by the associated plug 53. Thus, it will be understood that the plug 53 is removable with respect to the cap 52 and that the cap 52 is removable with respect to the extreme lower end of the tube 35. Also, the cap 52 is provided with a securing chain, one link of which is indicated at 57, which securing chain is fastened to the valve plate 33 in a manner, not shown; and likewise, the plug 53 is provided with a securing chain, one link of which is indicated at 58, which securing chain is fastened to the valve plate 33 in a manner, not shown. The first-mentioned securing chain prevents loss of the cap 52 when it is removed from the extreme lower end of the tube 51; and the second-mentioned securing chain prevents loss of the plug 53 when it is removed from the extreme lower end of the cap 52.

In service, the liquid lading is loaded into the tank body 11 through the hatch opening provided in the top of the

5

dome 15 with the hatch cover 16 in its open position, after the outlet valve mechanism 31 has been operated into its closed position by proper manipulation of the valve wheel 32 disposed in the dome 15. Thereafter, the hatch cover 16 is closed and sealed in place; whereupon the railway tank car 10 is transported to its destination. In order to unload the liquid lading from the tank body 11, the plug 53 is removed from the associated cap 52, while the outlet valve mechanism 31 occupies its closed position, and a suitable discharge conduit is secured in place in the cap 52, in an obvious manner. Thereafter, the hatch cover 16 is moved into its open position, and the valve wheel 32 is manipulated so as to operate the outlet valve mechanism 31 into its open position, with the result that the liquid lading flows by gravity from the tank body 11 through the outlet valve mechanism 31 in its open position and thence through the discharge conduit into the storage container, not shown. After the liquid lading is thus unloaded, the outlet valve mechanism 31 is returned back into its normal closed position, the discharge conduit is disconnected from the cap 52, and the plug 53 is returned into its normal position with respect to the cap 52. Ultimately, the hatch cover 16 is returned into its normal closed position.

In the transportation of many liquid ladings, particularly light oils containing some water, the difficulty is encountered that the water settles out of the lading and accumulates in the lower portion of the tank body 11, with the result that in cold weather, the water freezes and thus plugs the outlet valve mechanism 31 in its closed position. This problem is encountered in the transportation of benzene during the winter months; and it is for the purpose of melting the water mentioned that has accumulated in the lower portion of the tank body 11 that the composite heating coil 21 has one of its primary utilities. In this case, when the railway tank car 10 reaches its destination, the inlet fixture 23 is connected to a suitable steam line and the outlet fixture 24 is connected to a suitable drain line. The supply valve arranged in the steam line is then opened so as to cause live steam to be circulated through the heating coil 21, with the result that the layer of ice disposed in the lower portion of the tank body 11 and embedding the heating coil 21 and arranged below the liquid lading is melted. Upon melting of the layer of ice mentioned, the outlet valve mechanism 31 is unplugged, whereby it may be operated into its open position, so that first the water and then the liquid lading may be discharged from the tank body 11 to the exterior, in the manner previously explained.

Also, in passing, it is mentioned that other non-aqueous liquid ladings in cold weather become quite viscous; whereby it is necessary to heat or warm-up these ladings utilizing the composite heating coil 21, in the manner previously explained, so that these ladings may be readily unloaded from the tank body 11 through the outlet valve mechanism 31 in its open position.

The composition of water, as well as other impurities that tend to settle out of various ladings that are transported in the tank body 11 normally exhibit substantial corrosive effects upon the composite heating coil 21, particularly in view of the circumstance that the temperature thereof is frequently elevated to a relatively high value. Thus, it is highly desirable to prevent these corrosive effects upon the exterior surface of the composite heating coil 21 and upon the adjacent lower interior surface of the tank body 11, particularly since these areas of the interior of the tank body 11 are fundamentally subjected to the corrosive influences described. In order to achieve this objective, the surfaces mentioned are provided with metal coatings, and since the tank body 11 and the elements of the composite heating coil 21 are ordinarily formed of steel, it is highly advantageous that the surfaces mentioned be coated with nickel. More particularly, it is preferable that the exterior surface of the compos-

6

ite heating coil 21 be provided with a relatively thick nickel coating and that the lower interior surface of the tank body 11 be provided with a relatively thin nickel coating. The general objective of producing simultaneously the two nickel coatings mentioned may be readily achieved in accordance with the present method by the utilization of an aqueous chemical reduction type metal plating bath, and specifically by the utilization of such a chemical plating bath of the nickel cation-hypophosphite anion type, as explained more fully hereinafter.

Before proceeding with the description of the present method, reference is made to FIG. 5, wherein there is illustrated diagrammatically a system that may be advantageously utilized in carrying out the method. More particularly this system, essentially comprises, in addition to the tank body 11 in which the heating coil 21 is arranged, a storage tank 101 that is adapted to contain the plating solution mentioned, a launder 102, a cooler 103, a heater 104, two pumps 105 and 106 and two filters 107 and 108. The storage tank 101 may have an open top; and the bottom thereof is connected by a conduit 109 to the inlet of the pump 106, while the outlet of the pump 106 is connected to the inlet of the filter 108. The outlet of the filter 108 is connected to the bottom of the shell of the heater 104, and the top of the shell of the heater 104 is connected to a conduit 110, the outer end of which is arranged in communication with the hatch opening provided in the dome 15 when the hatch cover 16 occupies its open position. The launder 102 may have an open top; and the bottom thereof is connected by a conduit 111 to the inlet of the pump 105, while the outlet of the pump 105 is connected to the inlet of the filter 107. The outlet of the filter 107 is connected to the bottom of the shell of the heater 103, and the top of the shell of the heater 103 is connected to a conduit 112, the outer end of which is arranged in communication with the open top of the storage tank 101. The shell of the cooler 103 contains a heat exchange coil, indicated at 113; the inlet of the heat exchange coil 113 is connected via a manually operable valve 114 to a cold water supply pipe 115; and the outlet of the heat exchange coil 113 is connected via a manually operable valve 116 to a drain conduit 117. The shell of the heater 104 contains a heat exchange coil, indicated at 118; the inlet of the heat exchange coil 118 is connected via a manually operable valve 119 to a live steam supply pipe 120; and the outlet of the heat exchange coil 118 is connected via a manually operable valve 121 to a drain conduit 122.

In preparing the tank body 11 for the plating operation, the cap 52 is removed from the extreme lower end of the tube 35, as previously described in conjunction with FIG. 4; and a false cap 130 is secured to the extreme lower end of the tube 35; which false cap 130 carries a standpipe 131; the upper open end of the standpipe 131 projects upwardly into the lower portion of the tank body 11 and the lower open end of the standpipe 131 is arranged over the open top of the launder 102. More particularly, the upward projection of the upper open end of the standpipe 131 above the bottom wall of the tank body 11 establishes the desired head or level of the plating bath that may be maintained in the lower portion of the tank body 11, and specifically this upward projection of the upper open end of the standpipe 131 is such as to establish the plating bath level 132, above the composite heating coil 21, so that the composite heating coil is wholly submerged in the plating bath contained in the lower portion of the tank body 11.

Considering now the general mode of operation of the plating system, it will be understood that a plating solution may be arranged in the storage tank 101, as indicated at 133; which plating bath may be supplied via the pump 106, the filter 108, the heater 104 and the conduit 110 into the tank body 11 through the hatch opening in the dome 15 with the hatch cover 16 in its open position; whereby the plating solution accumulates in the tank body 11 as a

plating bath up to the level 132, as established by the upper open end of the standpipe 131. After this fill of the plating bath into the tank body 11, any further supply of the plating solution to the tank body 11 results in the overflow thereof from the lower portion of the tank body 11 through the standpipe 131 back into the launder 102. From the launder 102, the plating bath may be returned by the pump 105 via the filter 107 through the cooler 103 and thence via the conduit 112 back into the storage tank 101.

In the operation of the plating system, the plating solution passing through the heater 104 may be heated, if desired, by the passage of live steam through the heat exchange coil 118, for a purpose more fully explained hereinafter. Also, the plating solution passing through the cooler 103 may be cooled, if desired, by the passage of cooling water through the heat exchange coil 113, for a purpose more fully explained hereinafter.

Further, the plating system comprises a steam supply line 141 that is connected by a manually operable valve 142 to a supply conduit 143; and the extreme outer end of the supply conduit 143 may be suitably connected to the inlet fixture 23 of the composite heating coil 121. Also, the steam supply conduit 143 is provided with a pressure gauge, indicated at 144, so that the pressure of the live steam supplied into the composite heating unit 21 may be metered in order that the operator may know the temperature of the live steam that is supplied to the heating coil 21. Further, the outlet fixture 24 of the composite heating coil 21 is suitably connected to a drain conduit 145 in order that the condensate from the composite heating coil 21 may be carried to the exterior thereof.

Further, the plating system comprises a first longitudinally spaced-apart series of nozzles 151 disposed on one side of the tank body 11 and directed toward the intermediate portion of the exterior surface thereof; which nozzles 151 are connected to a cold water supply pipe 152 via an associated manually operable control valve 153. Finally, the plating system comprises a second longitudinally spaced-apart series of nozzles 161 disposed on the other side of the tank body 11 and directed toward the intermediate portion of the exterior surface thereof; which nozzles 161 are connected to a cold water supply pipe 162 via an associated manually operable control valve 163. It will be apparent that the lower portions of the exterior surfaces of the tank body 11 may be cooled, for a purpose more fully explained hereinafter, by water projected thereupon from the nozzles 151 and 161 when the corresponding valves 153 and 163 occupy their open positions.

As a constructional example of the railway tank car 10, the tank body 11 has a lading volume of 10,033 gallons, an inside diameter of 86½ in. and a length over the end heads of 33 ft. 9 in. The tube 35 has an inside diameter of 3¾ in. and projects below the extreme bottom exterior surface of the tank body 11 by 21½ in. The composite heating coil 21 stands 18 in. above the extreme bottom wall of the tank body 11; and the standpipe 131 may extend upwardly 3 in. above the top of the composite heating coil 21; whereby the level 132 of the plating bath that may be contained in the lower portion of the tank body 11 is 21 in. above the extreme bottom wall of the tank body 11; whereby the plating bath that may be contained in the lower portion of the tank body 11 comprises a volume of 1838 gallons, excluding the volume of the composite heating coil 21, with the tank body 11 in a substantially horizontal position, as indicated in the system of FIG. 5.

Turning now to the present plating method, the plating bath that is employed may be any one of a wide variety of plating baths of the character previously noted, such, for example, as disclosed in: U.S. Patent No. 2,532,283, granted on December 5, 1950 to Abner Brenner and Grace E. Riddell; U.S. Patent No. 2,658,842, granted on November 10, 1953 to Gregoire Gutzeit and Ernest J.

Ramirez; U.S. Patent No. 2,822,294, granted on February 4, 1958 to Gregoire Gutzeit, Paul Talmey and Warren G. Lee; and U.S. Patent No. 2,935,425, granted on May 3, 1960 to Gregoire Gutzeit, Paul Talmey and Warren G. Lee. Preferably, this plating bath is of the character of that disclosed in U.S. Patent No. 2,822,294, that is hereinafter termed an "L-P" plating bath; which plating bath essentially comprises an aqueous solution containing nickel cations, hypophosphite anions, lactic anions as a complexing agent and propionic anions as an exalting additive. Also, this L-P plating bath may advantageously contain lead ions in the general range 2 to 5 p.p.m. as a stabilizing additive, as disclosed in U.S. Patent No. 2,762,723, granted on September 11, 1956 to Paul Talmey and Gregoire Gutzeit.

Accordingly, the L-P plating bath essentially comprises an aqueous solution containing:

Nickel cations (as nickel sulfate) _____	m.p.l._____	0.07 to 0.08
Hypophosphite anions (as sodium hypophosphite) _____	m.p.l._____	0.225 to 0.230
Lactic ions (as lactic acid) _____	m.p.l._____	0.25 to 0.60
Propionic anions (as propionic acid) _____	m.p.l._____	0.025 to 0.060
Pb++ (as stabilizer) _____	p.p.m._____	2 to 5
pH _____		4.0 to 5.6

A specific and preferred example of the L-P plating bath has the following composition:

NiSO ₄ ·6H ₂ O _____	m.p.l._____	0.08
NaH ₂ PO ₃ ·H ₂ O _____	m.p.l._____	0.23
Lactic anion _____	m.p.l._____	0.30
Propionic anion _____	m.p.l._____	0.03
Pb++ _____	p.p.m._____	2
pH _____		4.5

A chemical nickel plating bath of this type may be employed directly to coat with nickel, surfaces formed of catalytic materials, the elements of Group VIII of the Periodic System consisting of iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium and platinum. Also, the surfaces of other industrial metals including copper, magnesium, aluminum and titanium, may be readily coated with nickel; and furthermore, even non-metallic surfaces may be coated with nickel, after some surface preparation, employing one of the catalytic materials mentioned, as disclosed in U.S. Patent No. 2,690,401, granted on September 28, 1954, to Gregoire Gutzeit, William J. Crehan and Abraham Krieg.

As well-understood in the metal-coating art, an aqueous chemical reduction type metal plating bath has a boiling point somewhat above 100° C. (ordinarily about 102° C.), and is characterized by minimum stability and a high plating rate at a temperature within the relatively high temperature range 88° C. to 98° C. and by maximum stability and a low plating rate at a temperature below this given range, whereby the plating rate decreases substantially as the temperature of the plating bath is reduced. This reference to "stability" pertains to the undesirable characteristic of a metal plating bath of this type concerning "spontaneous decomposition" thereof, with the resulting formation of "black precipitate" therethrough. Among the many factors causing instability of such a plating bath is the temperature thereof, whereby boiling of the plating bath is carefully avoided. Thus, since a high plating rate of the plating bath is desired, the ordinarily useful temperature range of a plating bath of this type extends from about 88° C. to about 98° C., as previously pointed out.

The specific plating rate-temperature character of the L-P plating bath of the present example is illustrated in the graph of FIG. 6, wherein it will be observed: the plating rate of this particular plating is about 0.8 mil per hour at 98° C. and about 0.4 mil per hour at

88° C., and substantially negligible at temperatures below about 40° C. Typical values are as follows:

Plating rate (microinches per hour):

	Bath temperatures (° C.)
800 -----	98
690 -----	95
400 -----	88
330 -----	85
83 -----	69
18 -----	56
3 -----	41

Considering now the present method, the interior surfaces of the tank body 11 and the exterior surfaces of the composite heating coil 21 are subjected to substantially conventional cleaning and surface preparation steps as follows:

(1) Any loose scale, dust, etc., is removed from the interior surfaces of the tank body 11 and the exterior surfaces of the composite heating coil 21 utilizing a hammer and vacuum cleaner, all in a conventional manner, it being understood that a person may enter the tank body 11 through the hatch opening in the dome 15, when the hatch cover 16 occupies its open position.

(2) The surfaces mentioned are then subjected to an alkali degreasing and cleaning step, utilizing an aqueous solution of "Enthone" cleaner, at approximately 185° F., about 6.6 ozs. of "Enthone" cleaner per gallon of water being employed to produce the cleaning solution. Specifically, the false cap 130 is placed upon the tube 35 and the volume of approximately 1838 gallons of this cleaning solution is introduced into the tank body 11 and allowed to stand therein for approximately ½ hour. Thereafter, the false cap 130 is removed from the tube 35 to allow draining of the cleaning solution from the tank body 11; which draining requires a time interval of about 23 min.

(3) The false cap 130 is then replaced upon the tube 35, and tapwater at ambient temperature, about 70° F., is introduced into the tank body 11 in covering relation with respect to the composite heating coil 21, the volume employed being approximately 1838 gallons, as previously noted. Again the false cap 130 is removed from the tube 35 so as to allow the rinse water to drain from the tank body 11.

(4) The false cap 130 is then replaced upon the tube 35, and an aqueous hydrochloric acid pickling solution is introduced into the tank body 11. The pickling solution is made up at a temperature in the general range 40° F. to 45° F. and comprises about 16% by weight of HCl. The previously mentioned volume of the acid pickling solution is introduced into the tank body 11. The valve 142 is opened slightly to allow a small amount of steam to pass from the steam supply pipe 141 into the conduit 143 and thence into the composite heating coil 21, so as to raise the temperature of the acid pickling solution up to the ambient, about 70° F. The valve 142 is then closed, and again the false cap 130 is removed from the tube 35 so as to allow the acid pickling solution to drain from the tank body 11.

(5) The false cap 130 is then replaced upon the tube 35, and the previously mentioned volume of hot rinse water, at a temperature of about 138° F., is introduced into the tank body 11, and allowed to stand therein for about 3 min.; and again the false cap 130 is removed from the tube 35 so as to allow the hot rinse water to drain from the tank body 11.

(6) The false cap 130 is then replaced upon the tube 35, and the previously mentioned volume of cold rinse water, at a temperature of about 40° F. to 45° F., is introduced into the tank body 11, and allowed to stand therein for about ½ hour, so as further to rinse, and also to cool, the tank body 11. Again the false cap 130 is removed from the tube 35 so as to allow the cold rinse water to drain from the tank body 11.

(7) The inside of the tank body 11 is then hosed down with tapwater through the hatch opening in the dome 15, while the false cap 130 is removed from the tube 35, so as to accommodate draining during this step.

Following these substantially conventional cleaning and surface preparation steps, the false cap 130 is again replaced upon the tube 35 and the L-P chemical nickel plating solution of the composition previously described is either placed in the storage tank 101 or made-up therein, which plating solution normally has a temperature of about 70° F. The pump 106 is then operated so that the plating solution is pumped from the storage tank 101 through the filter 103 and the heater 104 and thence via the conduit 110 into the tank body 11. Normally the heater 104 is not operated at this time, so that the plating solution delivered into the tank body 11 is at the ambient temperature of about 70° F., and a full volume of bath thereof is accumulated in the tank body 11 up to the level 132 as established by the standpipe 131 with the false cap 130 in place upon the tube 35 in the manner previously explained. The valve 142 is opened so that the steam is supplied from the steam line 141 into the conduit 143 and thence via the inlet fixture 23 into the composite heating coil 21. In the present example, the steam in the conduit 143 is at a pressure of 50# gauge having a temperature of about 297° F., as admitted into the inlet fixture 23. Of course, the steam in the composite heating coil 21 heats the same and, in turn, is condensed therein, as time proceeds, with the result that ultimately the condensate in the heating coil 21 flows therefrom via the outlet fixture 24 and through the drain conduit 145 to the exterior. As the temperature of the exterior surface of the composite heating coil 21 rises above the ambient, a thin layer of the plating bath contained in the tank body 11 and disposed in contact with the exterior surface of the heating coil 21 is elevated to a temperature substantially above that of the main body of the plating bath in the tank body 11. Specifically, the heating coil 21 comprises a workpiece that is immersed or submerged in the plating bath contained in the tank body 11 and shortly after the introduction of the steam into the interior thereof the exterior surface of the heating coil 21 is elevated to a temperature somewhat above 100° C., so that the temperature of a thin layer of the plating bath disposed in contact with the exterior surface of the heating coil 21 is maintained within the given range 88° C. to 98° C., corresponding to the temperature range of the high plating rate of the plating bath; whereby the exterior surface of the heating coil 21 is coated by chemical deposition from the plating bath contained in the tank body 11, in the usual manner. The thin layer of the plating bath in contact with the exterior surface of the heating coil 21 in turn heats the main body of the plating bath contained in the tank body 11, thereby to cool the same, so as to prevent boiling of the thin layer of the plating bath disposed in contact with the exterior surface of the heating coil 21, and so as to cause the temperature of the main body of the plating bath mentioned to rise gradually above the ambient temperature of about 70° F. as time proceeds.

The subsequent steps of the present method that are carried out are dependent upon whether or not it is desirable also to effect the deposition of a nickel coating upon the lower interior surface of the tank body 11 that is also submerged in the plating bath contained therein. First, it is assumed that it is desirable to obtain coating of the lower interior surface of the tank body 11 that is submerged in the plating bath; whereby in this case no action is taken by the operator that would bring about cooling of the main body of the plating bath contained in the tank body 11. Accordingly, as time passes, the temperature of the main body of the plating bath contained in the tank body 11 rises sufficiently above the ambient temperature so that nickel plating is initiated upon the lower interior surface of the tank body 11 that

11

is submerged in the plating bath contained therein. Of course, after the passage of an appropriate time interval, the temperature of substantially the whole body of the plating bath contained in the tank body 11 rises into the high plating rate temperature range, 88° C. to 98° C., whereby at this time the nickel coating of both the exterior surface of the heating coil 21 and the lower interior surface of the tank body 11 proceeds at the relatively high plating rate, as previously described.

After an appropriate time interval, the plating operation is arrested by closing the valve 142 in order to cut-off further admission of steam into the heating coil 21 and by removing the false cap 130 from the tube 35 so as to allow the plating bath contained in the tank body 11 to drain therefrom into the associated launder 102 disposed below the lower end of the standpipe 131. From the launder 102, the plating bath is pumped by operation of the pump 105 through the filter 107 and through the cooler 103 and thence via the conduit 112 back into the storage tank 101.

In carrying out the plating method as described above, it will be appreciated that a relatively thick nickel coating is deposited upon the exterior surface of the heating coil 21 and that a relatively thin nickel coating is deposited upon the lower interior surface of the tank body 11, as is desired for the present purpose, by virtue of the fact that the thin layer of the plating bath in contact with the exterior surface of the heating coil 21 held a relatively high effective temperature throughout a much longer time interval than did the main body of the plating bath that was in contact with the lower interior surface of the tank body 11. In passing, it is noted that the relatively large volume (about 1838 gallons) of the plating bath contained in the tank body 11 comprises a substantial "heat-sink," whereby the plating process, as described above, may be carried out for a time interval as long as about 4½ hours without effecting boiling of the plating bath contained in the tank body 11, notwithstanding the circumstance that steam at 50# gauge is continuously supplied into the conduit 143 connected to the inlet fixture 23 of the heating coil 21.

Now assuming that it is undesirable to effect any substantial nickel coating upon the lower interior surface of the tank body 11, the above described process may be modified so as to effect cooling of the main body of the plating bath contained in the tank body 11 during the nickel coating of the exterior surface of the heating coil 21 so as to maintain the temperature of the main body of the plating bath in contact with the lower interior surface of the tank body 11 below the normally effective plating temperature thereof.

The cooling mentioned may be achieved first by the conjoint operation of the two pumps 105 and 106, together with operation of the cooler 103. In this case, additional plating solution from the storage tank 101 is supplied by operation of the pump 106 through the conduit 110 into the tank body 11, with the result that the plating bath therein rises above the level 132 as established by the open top end of the standpipe 131, whereby the cool plating solution thus supplied into the tank body 11 moderates or cools the plating bath contained in the tank body 11 and causes overflow thereof via the standpipe 131 into the launder 102. The plating solution from the launder 102 is returned by the operating pump 105 through the filter 107 and the cooler 103 and thence via the conduit 112 back into the storage tank 101. In the cooler 103, the circulated plating solution is cooled in an obvious manner prior to the return thereof into the storage tank 101. In this case, some of the heat that is supplied to the main body of the plating bath contained in the tank body 11 from the heating coil 21 is removed therefrom by the circulation of the plating solution through the cooler 103 in which the heat mentioned is extracted from the system and passed to the exterior by virtue of the circulation of cooling water through the heat exchange coil 113 disposed in the shell of

12

the cooler 103 with the valves 114 and 116 in their open positions. By adjustment of the positions of the manually operable valves 114 and 116, the cooling rate of the circulated plating solution may be appropriately established so as to maintain the temperature of the main body of the plating bath contained in the tank body 11 well below the normally effective plating temperature range thereof.

On the other hand, this cooling rate of the circulated plated solution may be preset so as to allow the main body of the plating bath contained in the tank body 11 to rise into the lower extremity of the effective temperature plating range of the plating bath so as to achieve the coating of the lower interior surface of the tank body 11 with any desired exceedingly thin nickel coating.

Another modification of the previously described plating method is available to the operator without effecting circulation of the plating solution via the cooler 103. Specifically, the operator may simply open the valves 153 and 163 in order to cause cold water from the cold water supply pipes 152 and 162 to be sprayed by the nozzles 151 and 161 upon the opposite sides of the tank body 11; whereby the cold water thus running down the opposite sides of the tank body 11 cools the same so as to effect cooling of the lower interior surface of the tank body 11. This cooling of the lower interior surface of the tank body 11 causes another thin layer of the plating bath contained in the tank body 11 and disposed in contact with the lower interior surface thereof to be maintained at a temperature below the normal effective temperature plating range of the plating bath, as previously explained.

Also, this cooling effect may be selectively adjusted by corresponding manipulation of the manually operable valves 153 and 163; whereby any desirable relatively thin nickel coating upon the lower interior surface of the tank body 11 may be achieved by the simple expedient of correspondingly varying the cooling effect achieved by the spray nozzles 151 and 161.

Also in conjunction with the method, it is pointed out that it is not essential that the plating bath be placed in the tank body 11 at the ambient temperature of about 70° F. at which it is made-up or stored in the storage tank 101. More particularly, as the plating solution is delivered from the storage tank 101 into the tank body 11 by the pump 106 via the heater 104 and the conduit 110, the heater 104 may be suitably operated. Specifically, by appropriate opening of the manually operable valves 119 and 121, steam may be admitted into the heat exchange coil 113 of the heater 104, with the result that the plating solution passing therethrough from the storage tank 101 into the tank body 11 is preheated suitably above the ambient temperature. As a matter of fact, the procedure is recommended wherein the heater 104 is suitably operated to heat the plating solution delivered into the tank body 11 to a temperature of about 130° F. by operation of the heater 104. Also, if desired, the valve 142 in the steam pipe 141 may be opened just prior to the delivery of the plating solution from the heater 104 through the conduit 110 into the tank body 11. These alternative procedures are, in no way, fundamental to the successful carrying out of the present method, but they do bring about the initiation of early plating of the exterior surface of the heating coil 21, and the lower interior surface of the tank body 11, for the simple reason that the effective plating temperatures of the plating bath contained in the tank body 11 are reached in the plating operation almost immediately, when all of the required heat is not supplied by the heating coil 21, after the plating bath has been placed in the tank body 11.

Considering now a typical plating run or example of the present method: after appropriate cleaning and surface preparation of the exterior surface of the heating coil 21 and the lower interior surface of the tank body 11, a volume of approximately 1838 gallons of plating solution as a bath was placed in the tank body 11, with the false cap 130 in place upon the tube 35; which plating

bath contained in the tank body 11 was at the ambient temperature of about 70° F. This particular plating bath that was employed was of the L-P type, as previously described, and had the following specific composition:

Nickel cation -----m.p.l.	0.084
Hypophosphite anion -----m.p.l.	0.252
Phosphite anion -----m.p.l.	0.442
Lactic anion -----m.p.l.	0.30
Propionic anion -----m.p.l.	0.03
Pb++ -----p.p.m.	2
pH -----	4.45

In passing, it is mentioned that this plating bath had been previously used in another chemical nickel plating operation, thereby accounting for the content of phosphite anion therein of 0.442 m.p.l.; and in this connection, it is noted that when a chemical nickel plating bath is utilized in a chemical nickel plating operation, not only is nickel cation reduced to metallic nickel and deposited upon the workpiece that is undergoing the nickel plating operation, but also hypophosphite anion is oxidized to phosphite anion therein; all as well understood by those familiar with the chemical nickel plating operation.

Returning now to the present example, after the plating bath of the composition specified had been placed into the tank body 11, the valve 142 was opened in order to allow steam at 50# gauge into the conduit 143 and thence into the heating coil 21. The valve 142 was thus opened at 5:05 p.m.

At 5:10 p.m., it was observed through the hatch opening in the dome 15 that nickel coating had already begun upon the uppermost reaches 22 of the heating coil 21.

At 6:00 p.m. condensate began to flow from the outlet fixture 24 of the heating coil 21, and a sample of the plating bath contained in the tank body 11 was withdrawn therefrom and the temperature thereof was measured at 130° F. (54° C.). A nickel cation test was run on this sample of the plating bath and it was determined that the nickel cation concentration therein had been reduced to 0.076 m.p.l. Accordingly during this first 55 minutes of the plating cycle, all of the nickel coating had taken place upon the exterior surface of the heating coil 21, since the nickel cation concentration of the plating bath had been reduced from 0.084 m.p.l. to 0.076 m.p.l. and the temperature of the body of the plating bath contained in the tank body 11 was still only about 130° F. Moreover, at this time, there was no vapor issuing from the hatch opening in the dome 15, the hatch cover 16 occupying its open position.

At 6:16 p.m. very small wisps of vapor began to issue from the hatch opening in the dome 15 indicating a slight accumulation of vapor in the tank body 11 at this time.

At 7:00 p.m. another sample of the plating bath contained in the tank body 11 was withdrawn therefrom and the temperature thereof was measured at 165° F. (74° C.). A nickel cation test was run on this sample of the plating bath and it was determined that the nickel cation concentration therein had been reduced to 0.070 m.p.l. Accordingly during this 1 hour and 55 min. of the plating cycle, substantially all of the nickel coating had taken place upon the exterior surface of the heating coil 21 and very slight nickel coating had taken place upon the lower interior surface of the tank body 11, since the temperature of the main body of the plating bath was at this time only about 165° F.

At 8:00 p.m. another sample of the plating bath contained in the tank body 11 was withdrawn therefrom and the temperature thereof was measured at 180° F. (82° C.). A nickel cation test was run on this sample of the plating bath and it was determined that the nickel cation concentration thereof had been reduced to 0.068 m.p.l. Accordingly, during this 2 hours and 55 min. of the plating cycle, most of the nickel plating had taken place upon the exterior surface of the heating coil 21 with some nickel plating upon the lower interior surface of the tank body 11, since

the temperature of the main body of the plating bath was at this time only about 180° F.

At 9:00 p.m., another sample of the plating bath contained in the tank body 11 was withdrawn therefrom and the temperature thereof was measured at 190° F. (88° C.). A nickel cation test was run on this sample of the plating bath and it was determined that the nickel cation concentration thereof had been reduced to 0.064 m.p.l. Accordingly during this 3 hours and 55 min. of the plating cycle, the majority of the nickel plating had taken place upon the exterior surface of the heating coil 21 and a minority of the nickel plating had taken place upon the lower interior surface of the tank body 11, since the temperature of the main body of the plating bath had at this time reached 190° F.; which temperature is at the lower extremity of the normal high plating rate-temperature range of this plating bath.

At 9:05 p.m. steam began to issue from the outlet fixture 24 of the heating coil 21, indicating that the rate of condensation within the heating coil 21 had been reduced to a very low value and that the temperature of the heating coil 21 would now rise quite rapidly.

At 9:30 p.m. the plating operation was arrested by closure of the valve 142 in the steam supply pipe 141 and by the removal of the false cap 130 from the tube 35 so as to allow the plating bath contained in the tank body 11 to drain therefrom into the associated launder 102, from which it was pumped by the pump 107 back into the storage tank 101. Also another sample of this plating bath contained in the tank body 11 was withdrawn therefrom at this time and the temperature thereof was measured at 195° F. (91° C.). A nickel cation test was run on this sample of the plating bath and it was determined that the nickel cation concentration thereof had been reduced to 0.060 m.p.l. Accordingly during this 4 hours and 25 min. of the plating cycle, most of the nickel plating had taken place upon the exterior surface of the heating coil 21, although substantial nickel plating had also taken place upon the lower interior surface of the tank body 11.

The nickel cation concentration in this plating bath during the plating operation described above is illustrated graphically in FIG. 7; and the temperature of the main body of the plating bath contained in the tank body 11 during the plating operation described above is illustrated graphically in FIG. 8.

Referring now more particularly to FIG. 8, it will be observed that during the first 55 minutes of the plating operation, the temperature of the main body of the plating bath in the tank body 11 rose from 70° F. to 130° F., whereby during this time interval there was substantial nickel plating upon the exterior surface of the heating coil 11, but substantially no nickel plating was effected upon the lower interior surface of the tank body 11. This portion of the plating operation is referred to in FIG. 8 as the "primary" phase thereof.

During the next 3 hours of the plating operation, the temperature of the main body of the plating bath in the tank body 11 rose from 130° F. to 190° F., whereby during this time interval, the nickel plating rate upon the exterior surface of the heating coil 21 was substantially constant and at a relatively high value, whereas the nickel plating rate upon the lower interior surface of the tank body 11 was at a relatively low rate, by virtue of the relatively low average temperature of the main body of the plating bath. This portion of the plating operation is referred to in FIG. 8 as the "secondary" phase thereof.

During the next half hour of the plating operation, the temperature of the main body of the plating bath in the tank body 11 rose from 190° F. to 195° F., whereby during this time interval the nickel plating rate upon the exterior surface of the heating coil 21 was substantially constant and at a relatively high value, while the nickel plating rate upon the lower interior surface of the

tank body 11 was also at a relatively high rate by virtue of the relatively high average temperature of the main body of the plating bath.

Throughout the plating operation, there was no boiling of the plating bath contained in the tank body 11, since the highest temperature encountered by the main body thereof was 195° F., and the plating bath maintained its stability by the total absence of "black precipitate" therein. Moreover during the plating operation, the nickel coating that was plated upon the exterior surface of the heating coil 21 had a thickness in excess of 4½ mils indicating that the average plating rate was in excess of 1 mil per hour. On the other hand, the nickel coating that was plated upon the lower interior surface of the tank body 11 had a thickness of about 2 mils indicating that the plating rate was below ½ mil per hour.

Again referring to FIG. 8, it is pointed out that the foregoing plating operation was deliberately carried out involving the primary phase, the secondary phase and the tertiary phase, by virtue of the fact that it was desirable to achieve the relatively thick nickel coating upon the exterior surface of the heating coil 21 and the relatively thin nickel coating upon the lower interior surface of the tank body 11. It is noted, however, that either or both the secondary phase and the tertiary phase of the plating operation may be completely eliminated by effecting cooling either of the main body of the plating bath or of the tank body 11, as previously explained. In other words, after the main body of the plating bath contained in the tank body 11 has reached the highest desired temperature, further elevation of the temperature thereof may be readily prevented by either one, or a combination of both, of the two cooling procedures, as previously explained. Accordingly, if desired, it is possible to obtain any desired nickel coating of the exterior surface of the heating coil 21, without any substantial nickel coating of the lower interior surface of the tank body 11. On the other hand, in the event it is desirable to accentuate either the "secondary" phase, or the "tertiary" phase of the plating operation, this may be readily accomplished by appropriate preheating of the plating solution, prior to the introduction thereon into the tank body 11, utilizing the heater 104, in the manner previously explained.

Accordingly, it will be understood that in accordance with the present method, any desired thickness of the nickel coating may be applied to the exterior surface of the heating coil 21, without the application of any substantial nickel coating upon the lower interior surface of the tank body 11. On the other hand, substantial nickel coatings may be readily applied to both the exterior surface of the heating coil 21 and the lower interior surface of the tank body 11. In passing, it is noted that there is always a tendency for the nickel coating that is applied to the exterior surface of the heating coil 21 to have a thickness somewhat greater than that applied to the lower interior surface of the tank body 11, by virtue of the fact that the average temperature of the exterior surface of the heating coil 21 is higher than the average temperature of the lower interior surface of the tank body 11 throughout the normal operating time interval of the plating operation.

In the plating of a large number of tank bodies 11 successively, utilizing the plating system of FIG. 5, it will, of course, be necessary to regenerate the plating solution in the storage tank 101, by the supply thereto of nickel cations, hypophosphite anions and hydroxyl anions; all in a conventional manner, such, for example, as generally disclosed in U.S. Patent No. 2,658,839, granted on November 10, 1953 to Paul Talmey and William J. Crehan.

In view of the foregoing, it is apparent that there has been provided an improved and simplified method of depositing metal from an aqueous chemical reduction type metal plating bath having a boiling point somewhat above 100° C. and that is characterized by mini-

imum stability and a high plating rate at a temperature within the given range, 88° C. to 98° C. and by maximum stability and a low plating rate at a temperature below the given range, wherein the method comprises providing a plating bath of the character specified and having a temperature that is well below the given range, immersing in the plating bath a workpiece having that is to be coated, and heating the surface of the workpiece while it is immersed in the plating bath to maintain a thin layer of the plating bath disposed in contact with the surface of the workpiece at a temperature within the given range without raising the temperature of the main body of the plating bath into the given range, whereby the surface of the workpiece is coated with metal from the plating bath. Also, in accordance with the method, a relatively thick metal coating may be applied to the surface of a first workpiece and a relatively thin metal coating may be applied to the surface of a second workpiece, which coatings may be applied simultaneously by immersing the two workpieces throughout a given time interval in the plating bath mentioned; during the time interval, the surface of the first workpiece is heated while it is immersed in the plating bath to maintain a first thin layer of the plating bath disposed in contact with the surface of the first workpiece at a temperature within the given range, and the surface of the second workpiece is cooled while it is immersed in the plating bath to maintain a second thin layer of the plating bath disposed in contact with the surface of the second workpiece at a temperature below the given range; with the result that the surface of the first workpiece is coated at a high plating rate with metal from the plating bath during the given time interval to produce the relatively thick metal coating thereon, and the surface of the second workpiece is coated at a low plating rate with metal from the plating bath during the given time interval to produce the relatively thin metal coating thereon.

The present method is very advantageous as it may be carried out in a simple and economical manner, without danger of "spontaneous decompositions" of the plating bath, by virtue of the relatively low temperature of the main body thereof. Also, the method lends an exceedingly long life to the plating bath, accommodating ready plating therewith at a high plating rate, notwithstanding the accumulation of a phosphite anion concentration therein as high as 1.0 molar; whereby used plating baths of little utility in ordinary plating operations may be employed herein in an entirely satisfactory manner. Finally, the controls employed are exceedingly simple and may be readily established upon a routine basis.

Hereinafter, in certain of the claims, the temperature of 88° C. of the plating bath is referred to as the "precipitating" temperature thereof, since this temperature comprises approximately the lower extremity of the normal operating temperature range, 88° C. to 98° C., of a chemical nickel plating bath of the present type; whereby the plating rate of the plating bath at the "precipitating" temperature (T° C.) is about 50% of the plating rate thereof at 98° C.

While there has been described what is at present considered to be the preferred embodiment of the invention, it will be understood that various modifications may be made therein, and it is intended to cover in the appended claims all such modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. The method of simultaneously coating with metal the interior surface of a metal vessel and the exterior surface of a metal tube disposed within said metal vessel; said method comprising providing an aqueous chemical plating bath of the nickel-hypophosphite type having a boiling point somewhat above 100° C. and that is characterized by minimum stability and a high plating rate

17

at a temperature within the given range 88° C. to 98° C. and by maximum stability and a low plating rate at a temperature below said given range, placing a quantity of said plating bath in said metal vessel in contact with the interior surface thereof and in submerging relationship to the exterior surface of said metal tube, heating the exterior surface of said metal tube while it is immersed in said plating bath to maintain a first thin layer of said plating bath disposed in contact with the exterior surface of said metal tube at a temperature within said given range, and cooling the interior surface of said metal vessel while it is in contact with said plating bath to maintain a second thin layer of said plating bath disposed in contact with the interior surface of said metal vessel at a temperature below said given range, whereby the exterior surface of said metal tube is coated at a high plating rate with metal from said plating bath and the interior surface of said metal vessel is coated at a low plating rate with metal from said plating bath.

2. The method of simultaneously coating with metal the interior surface of a metal vessel and the exterior surface of a metal tube disposed within said metal vessel; said method comprising providing an aqueous chemical plating bath of the nickel-hypophosphite type having a boiling point somewhat above 100° C. and that is characterized by minimum stability and a high plating rate

18

at a temperature within the given range 88° C. to 98° C. and by maximum stability and a low plating rate at a temperature below said given range, placing a quantity of said plating bath in said metal vessel in contact with the interior surface thereof and in submerging relationship to the exterior surface of said metal tube, passing a hot fluid through the interior of said metal tube while it is submerged in said plating bath in said metal vessel to heat the exterior surface thereof in order to maintain a first thin layer of said heating bath disposed in contact with the exterior surface of said metal tube at a temperature within said given range, and passing a cooling fluid about the exterior of said metal vessel while it is in contact with said plating bath to maintain a second thin layer of said plating bath disposed in contact with the interior surface of said metal vessel at a temperature below said given range, whereby the exterior surface of said metal tube is coated at a high plating rate with metal from said plating bath and the interior surface of said metal vessel is coated at a low plating rate with metal from said plating bath.

No references cited.

RICHARD D. NEVIUS, *Primary Examiner.*

R. S. KENDALL, *Assistant Examiner.*