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PROTECTED METAL ARTICLE AND PROCESS
OF PRODUCING THE SAME

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This invention relates generally to the protection of ferrous metals, such as are employed in the industrial arts, from the effects of such reagents as occasion corrosion and/or embrittlement.

Corrosion presents a serious problem in the industrial arts and occasions a vast economic loss. We are here employing the term "corrosion" in its broad sense to include the ordinary action of atmospheric air and moisture on metals such as ferrous metals and also those reactions which are or simulate chemical and electro-chemical reactions and are occasioned by active reagents, such, for example, as acids and alkalis. That is to say, corrosion such as is here under consideration ordinarily results from contact between a metallic surface and a corroding reagent, and independently of the form in which the reagent exists.

An object of this invention is to provide a surface condition for ferrous metal articles which will resist deterioration occasioned by the active effect of contacting reagents.

Another object of the invention is to produce a surface coating for ferrous metal articles which will provide a satisfactory operative surface, such as a bearing or wearing surface, but which will, at the same time, resist the deteriorating effect occasioned by the action of such reagents as the article may be exposed to during use.

A further object of the invention is to produce a metal article such, for example, as a rod, tank, delivery conduit, wire, forging, casting, bar, sheet, or other shape, which is formed of a base metal, such as steel, iron or a ferrous alloy, but which is provided with a surface or surface condition such as will occasion effective resistance to the deteriorating effect of such reagents as the article is subjected to during its normal life.

A specific object of the invention is to produce a surface condition on ordinary iron and steel articles which will resist the embrittling effect occasioned by such reagents as hydrogen, hydrogen sulphide, etc.

One aspect of the invention involves providing a ferrous metal article with a corrosive-resistant coating and then so treating the coated article as to impregnate the pores, interstices, and/or minute crevices thereof with a second corrosion-resistant metal which is preferably employed in such minute quantities as to avoid the production of a second coating or at least a second coating of appreciable thickness.

The base metal from which the articles involved are fabricated, will ordinarily be a ferrous

metal, such as iron, steel, or one of the commercial ferrous alloys. The first coating will ordinarily be deposited on the ferrous metal by an electrolytic or similar process and will ordinarily consist of a relatively thin coating of a metal, such, for example, as nickel, which is noble with respect to the base metal. Microscopic and other examinations of such coatings have disclosed that no matter how carefully applied, they are not impervious. That is, they do not provide a uniform, unbroken coverage which extends throughout the entire extent of the surface of the article. On the other hand, such examinations have disclosed a pervious condition resulting possibly, or at least in part, from porosity, but, in any event, such as to render the base metal subject to attack at different points of its surface and even subject to the attack by such a mild corrosive agent as moist air.

In carrying forward our invention, we provide the surface of the base metal with a coating which is impervious to the passage of corrosive reagents. As above noted, this is accomplished by providing the base metal surface with a coating of corrosion-resistant metal and then by impregnating the coating metal with a metal which, at least in its final state, is resistant to the corrosive action of such reagents as may be encountered by the article during its commercial or industrial use.

A specific aspect of the invention is to produce an article, such, for example, as a sucker rod, which is immune to or at least highly resistant to the action of such corrosive and embrittling reagents as are likely to be encountered in well pumping operations. Sucker rods are composed essentially of ferrous metal and in use they are often subjected to the deteriorating effect of liquids which at least approximate the action of a combined solution of sodium chloride and hydrogen sulphide.

In producing a sucker rod embodying our invention, a rod of the desired size, shape, etc. is made from a base metal such as steel and it is subjected to such cleaning and preparatory operations as are necessary or desirable as a preliminary to electroplating. These operations may include, for example, sand blasting, pickling, and washing. The rod is then electroplated in an approved manner and under such conditions as to provide a dense, uniform coating of a corrosion-resistant metal such as pure nickel. While the thickness of the coating may vary considerably and while a coating of about four one-thousandths of an inch has given excellent re-

sults, nevertheless it is desirable to employ thin coatings ranging from about one ten-thousandth of an inch to about four one-thousandths of an inch (.0001"-.004") in thickness.

Nickel is a hard and substantially corrosion-resistant metal having at least slightly more noble characteristics than the ferrous metal of which the rod is basically formed and the thin coating so produced is in itself a protection for the surface of the sucker rod. The inherent porosity of this coating and the porosity and the surface crevices and interstices of the underlying base metal favor attack by such reagents as the rod is ordinarily subjected to during use. That is to say, the condition of the sucker rod, even after having been plated with a non-corrosive coating such as pure nickel, is such as to permit rapid deterioration by reason of corrosion and embrittlement when the rod is subjected to corrosive and embrittling reagents. The coated rod is, therefore, impregnated with a second corrosion-resistant metal which is preferably less noble than the base metal (ferrous metal) and is preferably capable of exerting an appreciable vapor pressure and producing the desired result when subjected to a definite degree of heat even at a temperature substantially below its melting point.

For conditions such as are encountered with sucker rods, zinc has disclosed itself to be an effective impregnating metal.

The impregnation may be accomplished in a number of ways. For example, a thin coating of zinc may be deposited upon the nickel coated sucker rod after which the rod is heated under conditions such as to accomplish a zinc impregnation of the nickel coating and also of the underlying surface of the base metal. The thickness of the zinc coating may vary and may be subject to modification to suit particular conditions, but a thin coating is preferred and highly satisfactory results have been accomplished with a zinc coating of less than $\frac{1}{10000}$ of an inch thick. This coating may be deposited upon the nickel either by electro-deposition or by a hot dipping process wherein the nickel coated sucker rod is submerged in a bath of molten zinc and maintained therein for an appreciable period or at least long enough to insure its receiving a substantially uniform coating of zinc. Where the sucker rod is subjected to a hot dipping, the zinc coating is ordinarily thicker than is necessary or desirable and the excess zinc may then be removed in any suitable manner.

Regardless of the particular manner in which the zinc coating is applied, the sucker rod is then subjected to a heat treatment carried on under conditions such as will insure complete impregnation of the nickel coating with zinc. The heating is preferably carried forward in a non-oxidizing atmosphere and under conditions such as to insure uniform heating of the sucker rod. This can be effectively accomplished in an induction furnace where the nickel coated articles are so placed that they lie within the magnetic field generated by the induction coils. The period necessary to bring the rods or coated articles up to the desired temperature will, of course, vary with the size of the articles.

We have found that the impregnation occurs throughout a relatively wide temperature range. Where nickel is employed as the primary coating and zinc is employed as the impregnating metal, the temperature of this heat treatment may vary from temperatures as low as 300° F. to tem-

peratures substantially above the melting point of zinc and it should here be noted that there is a temperature time relationship which is essential in order to obtain complete impregnation. For example, where an article, such as a nickel coated sucker rod is exteriorly uniformly heated throughout its length in an induction furnace and in a non-oxidizing or neutral atmosphere, a satisfactory impregnation may be obtained in a period of about ten minutes where the temperature of the rod is caused to approach 1800° F. Having in mind that the rod is comparatively cold at the beginning of the interval of ten minutes and that it does not reach its maximum temperature until the end of the ten minutes, it will be appreciated that the temperature of the rod is considerably below 1800° F. for a large portion of the ten minute interval. As lower temperatures are employed, the heating period is necessarily increased and for temperatures approximating from 350° F. to 400° F. the interval during which the article is maintained at that temperature should be extended to approximately three hours; additional time being, of course, required to bring the article up to that temperature. It will, however, be understood that this temperature time relationship also depends, for example, upon the character of the article involved, the character of the heating, the use to which the article is to be put, the size of the article, the thickness of the primary coating and/or the metal employed in the coating and/or the impregnating metal. Then too, where the article is such as to quickly attain the desired temperature, conditions may indicate a heating time materially shorter than the time above stated, but on the other hand, certain articles and certain uses may indicate a much longer heating period and particularly where the lower temperatures are involved.

The articles produced by a procedure such as here outlined are substantially free from embrittlement or at least from a dangerous degree of embrittlement for an extensive period of time, and even where they are subjected to embrittling reagents such as are ordinarily encountered in oil well pumping operations.

After the heat treatment, the article may be cooled to atmospheric temperature.

While it is difficult to precisely define what takes place during the impregnating heat treatment, such reactions as can be traced by subsequent examination of the article so treated apparently result from a condition of high affinity between the coating and the impregnating metal during at least some portion of the heating period. We are convinced that the resulting impregnation is occasioned by a mechanical and a chemical affinity between the two metals involved. The term "mechanical affinity" is employed to define an action comparable to ordinary capillary action which takes place when the impregnating metal is in a state or condition capable of responding to such an action. We assume that this takes place under conditions simulating capillary attraction and wherein the surface impregnated by the impregnating metal constitutes the capillary structure. Under such conditions it seems apparent that there is also a strong chemical affinity between the coating and the impregnating metals or that a condition is arrived at during the heating period where a combination of mechanical and chemical reactions result. One component of this combined reaction is an alloying of the two metals involved and that this contributes to a

chemical or metallurgical reaction and at the same time favors filling of the pores, interstices, etc. of the primary coating metal with the impregnating metal.

A sucker rod thus treated, i. e., provided with a primary coating of nickel and then subjected to an impregnating heat treatment in the presence of metallic zinc, is rendered highly resistant both to the corrosive and embrittling effect of the water solutions of sodium chloride and hydrogen sulphide to which it is normally subjected in use. We have also found that even where the base metal from which the article is formed is metallurgically such as to be highly susceptible to embrittlement, the procedure will have an important and beneficial effect. Where the base metal is metallurgically such that it is normally somewhat resistant to embrittlement, the procedure herein set forth will protect against embrittlement such as is ordinarily occasioned by industrial uses wherein the article is either continuously or intermittently subjected to a highly active embrittling reagent.

After the heat treatment of a nickel, zinc coated article, such as the sucker rod, it will be found that the zinc coating has materially decreased in thickness and, depending upon the conditions of the heating, may have decreased to such an extent as to have almost entirely disappeared. In this connection, it should also be pointed out that unless the atmosphere within the heating furnace is carefully controlled, some zinc oxide may appear on the rod in the form of an encrustation. This, however, is not objectionable unless formed in excessive amounts, and may be removed in any suitable manner after the article has cooled. Thus, it is apparent that a neutral or reducing atmosphere is not essential during the heat treatment, although it is highly desirable.

Highly satisfactory results have been accomplished in impregnating nickel coated steel sheets with zinc where the sheets are arranged in pack formation with zinc sheets intervening between the nickel coated steel sheets. These packs are preferably heated in a reducing atmosphere and preferably to a temperature somewhat below the melting point of zinc and for a time not only sufficient to occasion uniform heating of the pack, but also to accomplish the result. That is to say, the temperature time relationship heretofore mentioned, must be taken into consideration and the length of time must be such as to compensate for the low temperature employed.

The foregoing discloses that while it is not essential for the impregnating metal to be in intimate contact with the coated article at the initiation of the heat treatment, it is essential for the heat treatment to be carried on under conditions such that the article is subjected to direct contact with the impregnating metal as that metal passes through a condition approaching or approximating a colloidal or jelly-like state.

A further consideration of the pack treatment of the nickel coated sheets discloses that the zinc sheets of the pack may be used over and over again and that the desired impregnation of the nickel coated ferrous sheets is accomplished even though the zinc sheets are not materially reduced in weight and even though they are not in intimate contact with the nickel coated sheets throughout the entire surface of those sheets. From this it is apparent that during the heat treatment a portion of the zinc subjected to the heat treatment passes through a condition approximating a vapor state and in this condition

is highly active as an impregnating medium for the nickel coated ferrous sheets. With this in mind, it is apparent that such articles as nickel coated sucker rods need not be coated with zinc prior to the impregnating heat treatment. The zinc may be introduced into the induction furnace in the form of zinc metal powder and this powder, may be conveniently supported on the rod by means of an adhesive coating which is dissipated by the heat involved. Under such conditions the zinc powder undoubtedly passes through a condition simulating a vapor state and for that reason is effective as an impregnating medium.

All electroplating processes are poorly adapted for the corrosion proofing or coating of unpolished raw metal surfaces of such metals as steel. The trouble appears to be that the raw metal surface contains projections, recesses, pits, cracks, seams, and non-metallic inclusions, all of which have the tendency of interrupting the integrity of a protective coating. Then too, the electrolytic process itself favors the production of a coating of high porosity and one which is, therefore, not impervious to some reagents. Even so, no old procedure for protecting or producing a protective covering approximates the results accomplished by our new procedure in connection with corrosive and embrittling reagents.

A good continuous coating of zinc on iron will protect the iron from numerous forms of wet corrosion until the metallic zinc becomes dissipated or the integrity is interrupted. In some cases, the protection afforded by the zinc has subsisted until the zinc has wholly disappeared at least as a coating of appreciable thickness. Metallic zinc is considerably less noble and more anodic than ferrous metal, such as iron or steel. In fact, it is far more anodic than is necessary for protective purposes and because of this it is too rapidly dissipated. Furthermore, a straight zinc coating on iron or steel or even a straight zinc coating applied over a nickel coat on the iron or steel will permit exteriorly applied reagents to embrittle the iron or steel through the coating or coatings. Not only is this the case but the application of a straight zinc coating on nickel coated iron or steel seems to lower the resistance to the action of embrittling reagents and will in itself cause embrittlement of the iron or steel in numerous water solutions.

In the foregoing, the term "straight zinc coating" is used to distinguish from the application of zinc to the metal article in accordance with the procedure which is here involved in our invention. The nickel-zinc or like compound resulting from the application of our invention to a metal article is subdued and mild electrolytically, but is nevertheless sufficiently anodic and energetic, with relation to such base metals as the ferrous metals, to form a substantially permanent protective coating for such metals. It endures many times longer than straight zinc coatings and is many times more effective than pure nickel coatings.

Under certain conditions of application the advantageous results of our invention can be defined in terms of electrolytic action. That is to say, the metal (for example, nickel) employed in the primary coating is slightly more noble (and preferably only slightly more noble) than the base metal (iron, or such other base metal as is employed) and the impregnating metal (zinc) is substantially less noble than the base metal and less noble than the metal of the primary coating.

The heat treatment effects a combination such that there results in the surface of the treated article a degree of metal nobility and electrical potential that is approximately equal to that of the base metal, in at least some relations and for numerous sets of corrosive circumstances. Thus it is apparent that the coating, instead of being more noble and cathodic to the base metal (for example, iron) is slightly less noble and is anodic to the base metal (iron) which is now cathodic, with the result that such slight difference of potential as exists at the surface of the treated article is one in which the protective coating is slightly anodic with relation to the coated metal.

For numerous commercial applications it is desirable to treat the coating resulting after the impregnating heat treatment with chemical reagents for the purpose of removing zinc or other oxides and most, if not all, of the free surface zinc or other impregnating metal. This can be done with acids and acid solutions and phosphoric acid salts and acetic acid are recommended for this purpose. It, however, may be noted that a cyanide solution (such as NaCN), Parkerizing and Bonderizing solutions may also be employed. This step of removing oxides and excess impregnating metal improves the appearance of the treated article and also, to some extent, improves its corrosion and embrittling resistance characteristics.

We shall now set forth some specific examples.

Example #1

A sucker rod having a ferrous body with a diameter varying between $1\frac{3}{4}$ and $2\frac{1}{2}$ inches was first thoroughly cleaned by pickling. It was then electroplated with nickel to afford a nickel coating layer .006 of an inch in thickness. Thereafter the rod was electroplated with zinc to provide a zinc layer approximately .0002 of an inch in thickness. The rod was then heat treated at a temperature of approximately 675° F. with the heat treatment carried out for an over all period of approximately six hours in a non-oxidizing atmosphere. The rod was found to be corrosion resistant to an appreciably marked degree.

Example #2

22 gauge steel strip was first cleaned by pickling. Thereafter it was electroplated with nickel to provide a coating .0002 of an inch in thickness. It was thereafter electroplated with zinc to provide a coating .0001 of an inch in thickness. The strip was then coiled up in coils and such coils were placed in an electric furnace. Starting cold, heat treatment was continued in a non-oxidizing atmosphere for a total period of six hours. It took the first three hours to bring the furnace up to a temperature of 700° F. After this temperature was reached such temperature was maintained for a further period of three hours. The protected metal was found to be corrosion resistant to a marked degree and suitable for use in spray tanks which in use are subject to corrosion.

Example #3

The same metal, electroplated with nickel and with zinc as explained in Example #2, was heat treated in an electric furnace at a temperature which varied from a low of 700° to a maximum of 740° with heat treatment continued for an over all period of six and one-quarter hours. The resultant product while having valuable corrosion resisting characteristics was not as good

a product, so far as corrosion resistance was concerned, as the product of Example #2 above. This diminishing of the desired properties was apparently due to the employment of too high a degree of heat for too long a period.

Example #4

Ferrous screen cloth was first cleaned by pickling. It was then electroplated with nickel to provide a coating .00005 of an inch in thickness. Over this there was electroplated a layer of zinc .00015 of an inch in thickness. The plated wire cloth was then rolled up in rolls, each roll containing 300 feet of wire cloth. The rolls were then heat treated for a period of two and one-quarter hours at 700° F. The resulting wire cloth was found to have corrosion resistant characteristics to a marked degree. In heat treating screen cloth excellent results have also been attained by merely passing the screen cloth around a roll or group of rolls. Screen cloth having the nickel and zinc coatings of the thicknesses mentioned above was heat treated by passing the cloth around two rolls which were heated to 700° F. The screen cloth was in intimate contact with the heated roll surfaces for an approximate period of 45 seconds. When the screen cloth was coiled up and heat treated, the greater part of the relatively long heat treating period was required to bring the coiled material up to the temperature required for alloying the zinc with the nickel, whereas when the screen cloth was heat treated by direct contact with the heated roll, the cloth quickly reached the temperature of the roll and a relatively short period of forty-five seconds was sufficient to both raise the temperature of the cloth and cause the zinc to alloy with the nickel.

Example #5

Steel sheets .125 of an inch in thickness coated with nickel .002 of an inch in thickness were packed with interleaved thin sheets of pure zinc (i. e. commercial rolled zinc). The cold pack was placed in a furnace, the furnace temperature being 650° F. at the start and then raised to 710° F. and thereafter maintained at 770° F., which is somewhat below the melting point of zinc, for three hours. Satisfactory corrosion resisting coatings were obtained.

General example

Experience has demonstrated that ferrous base metals may be provided with electroplated nickel coating having a thickness varying from .00002 to .004 of an inch and with electroplated overlying zinc layers varying in thickness from .00005 to .0005 of an inch. Medium and large gauge products may be heat treated for a period from two to six hours at a temperature ranging between 600° F. to 750° F. The time and temperature may be varied depending on the thickness of the coatings and the bulk of the ferrous metal base. For example, a No. 9 steel wire having a coating thickness of .0003 of an inch of nickel and .0003 of an inch of zinc was heat treated by dipping in a heated salt bath. The best results were secured when the bath was maintained at a temperature of 1500° F. and when the wire was kept in the bath from two to five seconds, with the salt bath at 1300° F., the dipping period varied between two and ten seconds and with the bath at 1100° F. the dipping period should be four to sixty seconds.

Experience with the foregoing products and examination and test of specimens and test pieces

has demonstrated that the heat treatment causes the zinc or portions thereof to become alloyed with the underlying nickel coating. The extent to which alloying occurs varies in accordance with the thickness of the coatings and also in accordance with variations in the heat treatment. Alloying will vary from complete alloying extending through the nickel coating to partial alloying wherein there is a lower stratum or layer of nickel adjacent the ferrous base which is unalloyed with zinc having superimposed thereon an alloyed zone or zones of nickel and zinc. In some instances unalloyed zinc is also present. While improved corrosion resisting characteristics are attained in all cases, present experience demonstrates that the best corrosion resisting characteristics are afforded when the alloying of the underlying nickel only extends part way through the nickel layer, leaving unalloyed nickel adjacent the ferrous base.

Microscopic examination of a typical nickel-zinc alloy formed by carrying out the present process shows that the alloy has a stratified appearance, and analysis shows that the nickel and zinc, in what are for convenience termed the strata or layers of alloy, conforms in structure and composition to the well known nickel-zinc alloy system as follows:

Alpha-----	Up to 28% Zn
Beta (sub-one)-----	50-44% Ni
Gamma prime-----	24-20% Ni
Gamma-----	20-13% Ni
Delta-----	12-10% Ni

Tests have demonstrated that the presence of substantial amounts of the gamma and gamma prime components of the nickel-zinc alloy insure high corrosion resisting characteristics. This indicates that in the best practice of the invention the temperature-time relationship should be such as to develop a nickel-zinc alloy structure conforming to the alloy system mentioned, and in which the gamma and gamma prime components or portions of the structure are well developed. By carrying out the process in the manner heretofore described such conditions will be found to exist.

Due to the fact that the heat treatment is effected at a temperature substantially below the melting point of nickel, the nickel layer is not alloyed with the underlying ferrous base but remains bonded thereto by what may be termed the "electrolytic bond" which is secured by the nickel plating step of the process.

Experience and tests have furthermore shown that desired impregnation and creation of the described nickel-zinc alloy or alloys may be attained when the heat treatment is effected at temperatures substantially below the melting point of zinc. Furthermore, by heat treating at such temperatures zinc losses are minimized.

When nickel is plated on a ferrous base and heat treated, the alloying of the nickel with the iron will depend on two factors, viz. the temperature and the time duration of heat treatment. Substantially no appreciable alloying of the nickel with the iron base will take place when a large article such as a sucker rod, is placed in a furnace and in about ten minutes is caused to approach a temperature of 1800° F. A greater part of the relatively short heating period is consumed in raising the temperature of the relatively massive cold rod and the rod itself is not maintained heated above the nickel iron alloying temperature (i. e. 1300° F.) for a long enough period

to permit appreciable alloying of the nickel and the ferrous base. With smaller articles heated to lower temperatures and for still shorter periods of time, such as the iron wire mentioned in the general example above, there will also be no appreciable alloying of the nickel with the iron. Furthermore, when still lower temperatures such as between 600° F. and 750° F. are employed the heating period can be extended to a period approximating from two to six hours without substantial alloying of the nickel with the iron. No appreciable alloying of the ferrous base with the nickel layer will take place at temperatures below about 1300° F. Above that temperature, alloying of the ferrous base and the nickel will occur only if they are held at such elevated temperature for a time interval longer than that necessary to cause the zinc to alloy satisfactorily with the nickel. According to the present invention the temperature-time relations of the heat treatment are such that while there is alloying of the zinc with the nickel to a substantial and readily appreciable extent there is substantially no appreciable alloying of the nickel with the underlying ferrous base.

The foregoing discloses that insofar as our invention involves procedure, an important feature of the procedure is the impregnating heat treatment and the temperature-time relationship involved by that treatment. While it is difficult to set forth a rule for definitely defining this temperature-time relationship, it may be said that the heat treatment must continue for a time such that the articles treated are uniformly heated to substantially the temperature of the heat treatment and the impregnating metal is caused to pass through a condition approaching or approximating a colloidal or jelly-like state. If this rule is adhered to, it will be found that impregnation is satisfactorily accomplished.

While we have disclosed several modifications of the procedure herein involved as our invention, it will be apparent that other modifications may be made without departing from the spirit and scope of the invention and it will likewise be apparent that articles here defined as embodiments of the invention may be varied greatly within the contemplation of the invention as defined by the appended claims.

This application is a continuation in part of our copending application Serial No. 237,924, filed October 31, 1938.

What we claim is:

1. The method of increasing the corrosion resistant characteristics of ferrous base metal articles, which comprises electroplating directly upon the ferrous base a coat of nickel, then electroplating the nickel coating with zinc, and then sealing the pores resulting from electroplating by heat treating the composite electroplated article to a nickel zinc alloying temperature and under temperature-time relations at which there will be no substantial alloying of the nickel with ferrous base, to cause impregnation into the pores left by electroplating while maintaining the nickel unalloyed with the ferrous base, and with the zinc alloyed only with the nickel.

2. The method of protecting the surface of a ferrous article against corrosion which comprises electroplating directly upon the surface to be protected a coat of nickel, heating the article to a temperature above 300° F. and preferably somewhat below the melting point of zinc, while exposing the outer surface of the nickel to hot non-liquefied zinc to impregnate and fill pores

of the nickel with nickel-zinc alloy and leave the ferrous base unalloyed with nickel and leave free zinc as the exterior coating.

3. The method of protecting the surface of a ferrous article against corrosion which comprises electroplating directly upon the ferrous base of the article a coat of nickel, depositing zinc upon the nickel coating to provide an intermediate article consisting of base metal coated with nickel in turn coated with zinc as the outermost metallic layer, heat treating the said intermediate article at a temperature above 300° F., preferably somewhat below the melting point of zinc, and substantially below the melting point of nickel, to impregnate and alloy the outer portion of the nickel coating with zinc while leaving the ferrous base unalloyed with the nickel.

4. The method of protecting a ferrous metal article against corrosion which comprises electroplating directly upon a ferrous base a coat of nickel, and sealing the pores of the nickel plate with a nickel-zinc alloy by heat treating the nickel plate in the presence of zinc alone at a temperature above 300° F. and preferably somewhat below the melting point of zinc to impregnate the pores remaining after electroplating, while maintaining the nickel unalloyed with the ferrous base.

5. The method of protecting the surface of a ferrous article against corrosion which comprises electroplating directly upon the surface to be protected a coat of nickel, applying zinc to the nickel coating, and heat treating the article at a temperature above 300° F. and preferably somewhat below the melting point of zinc to produce a pore-sealing corrosion-resisting nickel-zinc alloy protective coating while leaving the ferrous base unalloyed with the nickel, and with the zinc alloyed only with the nickel.

6. A corrosion-resisting article comprising a base of ferrous material having a layer of nickel electroplated directly thereon, the pores remaining after electroplating being sealed by complete impregnation with an alloy consisting of nickel and zinc, the nickel being electrolytically bonded to the ferrous base material but unalloyed therewith, the outermost strata of said article including only nickel and zinc.

7. A corrosion-resisting article comprising a ferrous base having a nickel coat electroplated

directly thereon and unalloyed to the ferrous base, a zinc coat on the nickel alloyed thereto and a substantially pure unalloyed zinc outer surface.

8. The method of producing a corrosion-resisting outer coating on a ferrous base which consists in electro-depositing a dense uniform coating of nickel of a thickness within the range of 0.001 and 0.004 of an inch directly thereon, then electro-depositing directly onto said nickel coating a coating of zinc less than 0.0001 of an inch in thickness, and finally heating said composite consisting of the base and nickel and zinc coatings in a non-oxidizing atmosphere to a temperature within the range of 300° F. to the melting point of zinc for a time sufficient only to impregnate and permeate the pores of the nickel coating.

9. The method of producing a corrosion-resisting coating on a ferrous base which consists in electrodepositing a dense uniform coating of nickel directly onto said base of a thickness within the range of .0001 and .004 of an inch, then electrodepositing directly on said nickel coating a coating of zinc less than .0001 of an inch in thickness, and finally heating said composite in a non-oxidizing atmosphere to a temperature within the range of 300° to 400° F. for a time sufficient only to impregnate and permeate the pores of the nickel coating and leave free zinc on the exterior surface thereof.

10. The method of producing a corrosion resisting coating on ferrous base screen cloth which consists in electrodepositing a dense uniform coating of nickel directly onto said ferrous base screen cloth, said nickel coating having a thickness of not more than .00005 of an inch, then electrodepositing directly on said nickel coating a coating of zinc of not more than .00015 of an inch in thickness, and finally heat treating said composite article by passing said composite screen cloth over rolls heated to approximately 700° F.; the screen cloth being in contact with said heated rolls for a period of approximately 45 seconds to thereby impregnate and permeate the pores of the nickel coating and leave free zinc on the exterior surface of the article.

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CERTIFICATE OF CORRECTION.

Patent No. 2,315,740.

April 6, 1943.

JAMES M. SCHOONMAKER, JR., ET AL.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, first column, line 52, for "as" second occurrence, read --to--; page 6, second column, line 9, claim 8, for "0.001" read --0.0001--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of May, A. D. 1943.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.