

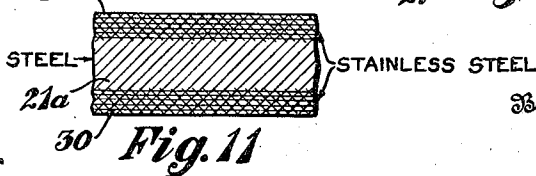
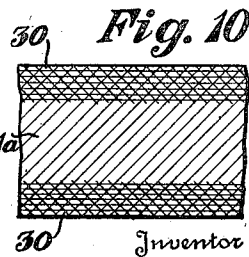
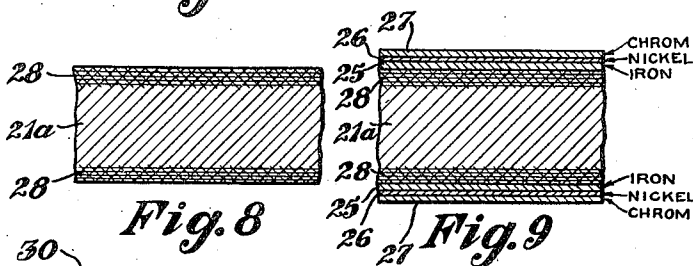
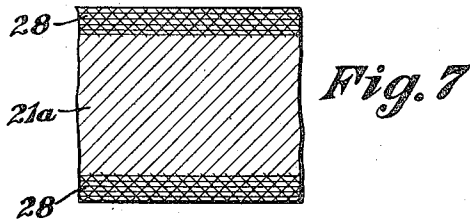
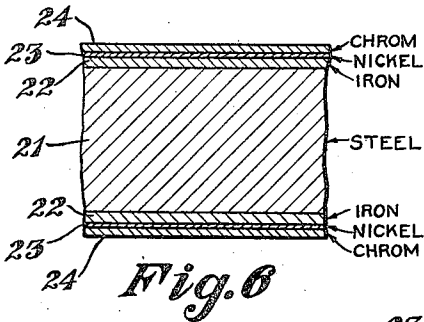
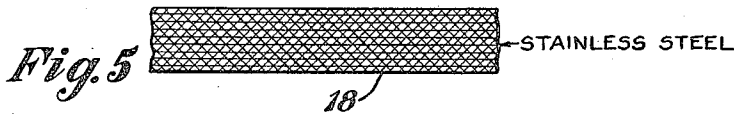
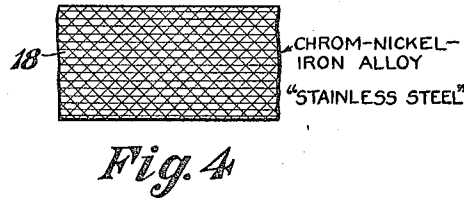
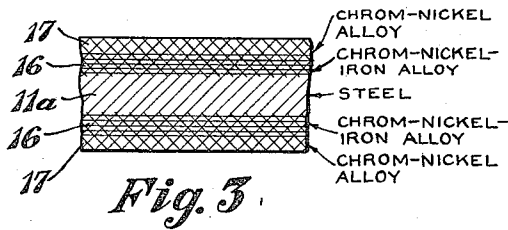
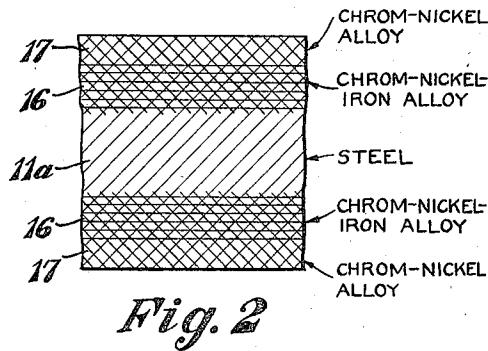
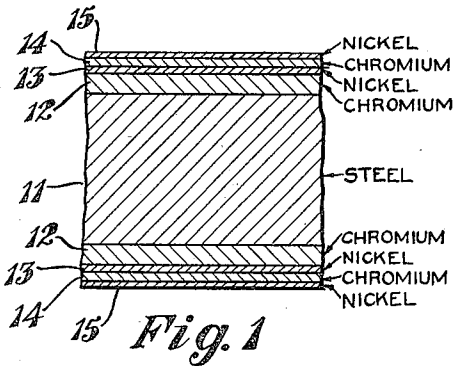
June 25, 1946.

J. S. NACHTMAN

2,402,834

MANUFACTURE OF DUCTILE STAINLESS CLAD ROLLED STEEL STRIP

Filed July 12, 1941



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UNITED STATES PATENT OFFICE

2,402,834

MANUFACTURE OF DUCTILE STAINLESS
CLAD ROLLED STEEL STRIP

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Application July 12, 1941, Serial No. 402,155

4 Claims. (Cl. 204—37)

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The invention relates to the manufacture of stainless steel. More particularly the invention relates to the manufacture of strip, sheet or wire products composed of stainless steel and the like, and to the manufacture of steel strip, sheet or wire products surfaced or clad with stainless steel and the like; any of which products are further characterized by their ability to withstand severe deep drawing, stamping or forming operations.

The term "stainless steel" is used in a broad and not a restricted sense in this application, meaning an alloy steel which may include, either chromium or chromium and nickel as an alloying agent in sufficient quantities to make it rust and corrosion resistant; or which may include chromium or chromium and nickel together with any one or more of the following elements as alloying agents: cobalt, tungsten, manganese, copper, silicon, vanadium and iron, in sufficient quantities to make it rust or corrosion resistant.

It is old to provide iron or steel or stainless steel articles with one or more electroplated coatings of nickel, chromium, copper, cadmium, cobalt, silver, or iron and to then heat the same to alloy the plated coatings to each other or to the base stock, or both, to form a rust or corrosion resistant surface for such articles. However, prior art articles or products so made, have always been rigid articles, that is, products having their final shape before being electroplated and heated. The prior art has recognized the difficulties encountered in obtaining adherence of the coatings, or in obtaining coatings which are not too brittle. And finally, the metal of the rigid prior art articles or products has such large grain size that it is not ductile and cannot withstand deep drawing, stamping, or forming operations.

The manufacture of products having stainless steel surfaces is not new, but such products also have a relatively high cost and as far as I am informed cannot be subjected to deep drawing, stamping or forming operations. Moreover, in so far as I am informed, no steel strip, sheet or wire, surfaced or clad with stainless steel, has ever been made before my invention, which is adapted for withstanding severe deep drawing, stamping, or forming operations, after being so surfaced or clad.

The manufacture of stainless steel strip, sheet or wire adapted for withstanding deep drawing, stamping, or forming operations is not new, but the cost of producing the same in accordance with prevailing practice, particularly in the thinner gauges, is extremely high.

Moreover, in the manufacture of stainless steel

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in accordance with prevailing practice, the alloying agents are incorporated in the molten steel either before or while pouring the same into the ingot molds, and there is a scrap loss of the alloying materials in the scrap metal formed incident to the usual rolling, heating and pickling steps carried out in producing thin gauge stainless steel strip and the like from ingots. Since these alloying agents have a high cost, the expense due to the scrap loss of the alloying agents is relatively high.

Moreover, when different analyses finished stainless steel alloy products are desired, different heats must be made for each different alloy desired, and the processing of the same to form the finished products must be controlled in accordance with the requirements of the particular alloy being rolled or worked.

All of these factors, together with many others, increase the cost of making stainless steel strip, sheet and wire products of different analyses, so that the cost of such products is very high as compared to the cost of similar products made of ordinary steel which is relatively cheap.

It is therefore a principal object of the present invention to provide methods of making stainless steel and stainless clad steel strip, sheet or wire products, particularly in the thinner gauges, which can withstand severe deep drawing, stamping and forming operations.

Moreover, it is an object of the present invention to provide methods of making stainless steel and stainless clad steel products much cheaper than the same can be made in accordance with prevailing practice.

Also it is an object of the present invention to materially reduce the cost of making stainless steel and stainless clad steel strip, sheet or wire products and to at the same time produce a stainless or stainless clad product which can be subjected to severe deep drawing, stamping and forming operations.

Moreover, it is an object of the present invention to utilize a relatively cheap rolled steel strip and the like as a base or raw material for making stainless or stainless clad steel strip and the like in order to materially reduce the cost of the finished product.

Also, it is an object of the present invention to prevent any substantial loss of expensive alloying agent in making stainless and stainless clad strip products and the like by electroplating the more expensive alloying agents in accurately controlled amounts upon a relatively cheap steel strip base and the like of such gauge that sub-

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sequent operations upon the same produce little if any scrap loss.

Likewise, it is an object of the present invention to reduce the cost of making stainless and stainless clad steel strip products of different analyses by changing the analysis by varying the alloying metals and thicknesses thereof electroplated upon a relatively cheap steel strip base which enables a very accurate control of the analysis and a relatively cheap cost of production of the finished product as compared with the prevailing practice of changing the analysis of the metal in the original heat thereof.

I have discovered that by alternately heat treating and cold rolling a relatively cheap rolled steel strip or the like having a plurality of some or all of the alloying metals electroplated thereon, a finished stainless or stainless clad steel product can be made having good ductility and such grain structure that it can withstand deep drawing, forming or stamping without damage or rupture.

I have also discovered that by coordinating the thickness of the steel base, the thickness of the successive layers of alloying metals electroplated upon the steel base, and the subsequent alternate heat treating and cold rolling operations; the alloying metals can be completely diffused into the base metal so as to form a uniform and homogeneous stainless steel alloy of the alloying and base metals.

I have further discovered that by a control and coordination of the thickness of the steel base, of the thickness of the successive layers of alloying metals electroplated upon the steel base, and of the subsequent alternate heat treating and cold rolling operations; the alloying metals can be completely diffused into surface portions of the base metal so as to form a steel strip having a uniform and homogeneous stainless steel alloy of the alloying and base metals on the surfaces thereof.

Moreover, some of the alloying metals may be incorporated in the cheap steel base stock in accordance with usual practice, such as vanadium, cobalt, tungsten, copper and silicon; before other alloying metals are plated on the base stock.

Many of the plating metals just mentioned are brittle when electroplated and are not well bonded to the adjacent layers of plated metals or base metal and will crack or peel if cold rolled. However, if the electroplated stock is heat treated to anneal the coating and base metals and to partially alloy the coating and base metals to each other, the heat treated plated stock can be cold rolled or worked to some extent without any danger of cracking or peeling. With each successive alternate heating and cold rolling operation the ductility of the product is increased and the diffusion and alloying of the metals progresses.

Moreover, the diffusion and alloying of the plating and base metals is completed in a much shorter time when the plated stock is alternately heated and cold rolled or worked, than when it is attempted to completely diffuse the plating and base metals by a long soaking heating operation without any cold rolling. This is believed to be due to the fact that with each cold rolling operation the thickness of the plated metals, or what remains of the same, is reduced and consequently the distance through which diffusion and alloying must take place is reduced.

Also, the alternate heating and cold rolling of the plated stock refines the grain structure of the

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component metals and of the ultimate alloy metal so as to permit the product to be deep drawn, stamped or formed severely, as distinguished from prior art plated heat treated products in which grain growth occurs and large grain size results which prevents the material from being drawn, stamped, or formed to any extent without damage or rupture.

The heat treating steps may each be carried out at a desired or selected temperature within the range of 1100° F. to 2500° F., the higher that the temperature utilized for each heating step is, the shorter is the time required for such heating step and each succeeding heating step, and the more rapid is the diffusion of the base and plating metals.

When complete diffusion is desired throughout the stainless steel strip, the temperature of any of the successive heating steps may be within the stated range of 1100° F. to 2500° F.

When making stainless clad steel; wherein complete diffusion takes place in the outer surface zones of the base metal, but not entirely through the base metal, all heating steps except the last may be at a selected temperature within the stated range of 1100° F. to 2500° F.; and the temperature of the last heat treatment should not be above the critical temperature of the steel base metal which is for most all relatively cheap steels that may be used as the base metal, about 1800° F.

The heat treatment may be carried out in almost any type of conventional furnace, that is, in either a box type or continuous type furnace. In either type of furnace, it is preferred that a special or controlled atmosphere be used, that is, one which is reducing in character, or at least non-oxidizing. It is, however, not absolutely necessary to use a controlled atmosphere, but if the atmosphere is not controlled and is oxidizing, it is necessary to pickle the material after heat treatment and before cold rolling; and in a great many instances the oxides of the alloys formed are difficult to remove.

Thus, the oxide formed when a chrome, nickel, iron alloy is heated to 2500° F. under oxidizing conditions is practically impossible to remove and care should be taken to prevent the formation of such oxides during heat treatment. If the formation of an oxide on the surface of the plated stock is not prevented during heat treatment, or if the same is formed and is not removed after heat treatment, it will be rolled into the stock and may ruin the stock or stock surface when subsequent cold rolling operations are carried out.

Specific examples of the manufacture of stainless and stainless clad steel strips and the like are set forth below. It will be noted that some of the examples only call for two heat treatments and one cold rolling, or for two heat treatments with an intermediate cold rolling and a final skin pass. It may be stated generally that in order to carry out the present invention, at least two heat treatments and at least one cold rolling operation between said two heat treatments of the electro-plated base stock must be carried out.

However, by increasing the number of alternate heat treating and cold rolling or cold working operations which are carried out, the deep drawing, forming and stamping characteristics of the resultant product will be materially benefited. Likewise, an increase in the thickness of the layers of alloying metals plated on the base metal will require an increase in the number of alternate heat treatments and cold rollings required

to obtain the desired qualities in the final product.

Also, as shown in some of the succeeding examples, the alloying metal or metals may be plated on the base stock, heat treating and cold rolling then performed, then more alloying metal or metals may be plated on the stock followed by heat treatment and cold rolling. This procedure may be incorporated in any of the examples and essentially consists in reducing the thickness of the stock intermediate plating operations, which results in reducing the total time of heating required for obtaining complete diffusion. The total time of heating means the sum total of the times of heating of all of the heat treatment steps carried out.

The various alloying metals plated on the base stock may be plated in any desired or selected sequence in order to give the desired composition. If the number of electroplated layers in any instance is increased and the thickness of each layer decreased correspondingly, in order that the desired composition results, the total time of heating required for obtaining the desired diffusion will be decreased.

Thus, it may be said that the number of heat treatments, the time of heat treatment, and the number of cold rollings required in accordance with the present invention is determined by the thickness of the plated layers, the number of plated layers, and the qualities desired in the final product; it being understood that at least two heat treatments and at least one cold rolling of the plated base stock are always required.

Since the procedures for electroplating the metals mentioned herein are well known in the art, these procedures, the types of electroplating solutions, and the preparation of the base metal are not described herein. It is sufficient to say that the strip steel stock is to be properly cleaned, and etched when necessary, prior to electroplating; and that any of the well known plating solutions are to be employed for electroplating the layers of component metals.

The number of layers of plated metals and the thickness thereof, and therefore the resulting composition due to diffusion is under accurate control, because the metals are applied by electroplating operations; and therefore any composition of stainless steel can be easily produced to any desired accuracy. Accordingly, the present invention provides for great flexibility of operation in producing any desired product.

In addition to other remarks made herein concerning the cold rolling or cold working operations following heat treatment operations, the same smooths out the plated heat treated coatings and reduces variations in the thickness thereof, thus contributing to the uniformity of the product produced. The cold rolling or cold working also closes up the pores of the electroplated metals and reduces porosity. Likewise, the cold rolling or cold working elongates surface grains, thus preventing the formation of stretcher strains when the material is subsequently deep drawn, formed or stamped.

Also, the surface appearance of the finished material can be controlled by the final cold rolling; for example, by using bright, smooth, polished rolls the surface of the finished material will be bright, and by using sand blasted rolls, the surface of the finished material is given a satin finish.

In connection with the manufacture of stainless clad strip steel, as distinguished from stainless strip steel, in accordance with the present in-

vention, the same procedures are followed except that the ratio of the thickness of the plated metals to the base stock may be less; a greater number of thinner coating layers may be used which will shorten the time and depth of diffusion of the coating layers into the base stock; and preferably a layer of iron will be first plated on the base stock to reduce or prevent diffusion into the base stock.

Moreover, the use of a layer of plated iron next to the base stock in making stainless clad strip steel will provide a more ductile and rust resistant clad product.

It should further be mentioned, that the stainless steel strip and the stainless steel surfaces of the stainless clad steel strip made in accordance with the present invention are essentially the same except that the stainless steel of the stainless clad steel strip will be substantially free of carbon and of impurities, because these materials will be retained in the base stock; while the stainless steel strip will contain the carbon and impurities present in the base stock.

The invention is further illustrated by the following examples:

Example 1

In making 18% chromium, 9% nickel stainless steel strip, the nickel and chromium may be plated in alternate layers on a relatively cheap steel strip; and at least two diffusion heat treatments and cold rolling following each heat treatment to give quick diffusion may follow the plating. For instance, a low carbon steel strip .090" thick may be electroplated on each side with a layer of .008" of chromium, followed by an electroplated layer on each side of .002" of nickel, followed by an electroplated layer on each side of .00435" of chromium, and finally with a layer on each side of .001635" of nickel.

The strip is then heat treated at a temperature within the range of 1100° F. to 2500° F., say at 1800° F. for one to five hours or longer in a non-oxidizing atmosphere to anneal the base metal and plated metals and to partially alloy the plated metals with the base metal and with each other.

The time of treatment depends upon the thickness of the plated metals, upon the time and temperature of the subsequent heat treating operation, and upon the type of furnace used. The higher the temperature used, the shorter will be the time of treatment, and for any selected temperature, the longer the time of treatment, the more diffusion will result.

The strip is then cold rolled to a thickness of .070" and reheated to a temperature within the range of 1100° F. to 2500° F. for a sufficient time to give complete diffusion of the chromium and nickel with the iron in the steel strip.

This step is then followed by cold rolling the stock to a finished gauge of say .040" thick, the resulting strip being a stainless steel strip containing approximately 18% chromium, approximately 9% nickel, and approximately 73% iron.

In this example, as well as in succeeding examples, the base stock or raw material may be either hot rolled pickled steel strip, or cold rolled steel strip either annealed or unannealed.

The time of the second heat treating operation was not given above because it depends upon the amount of diffusion resulting from the first heat treatment step, which in turn depends upon the temperature and time of treatment of the first step. However, if the second heat treat-

ment step is also at say 1800° F., the time of treatment may again be one to five hours or longer. If either of the heat treatments are at a lower temperature in the stated range, the time of treatment will be ordinarily longer, or if at a higher temperature, the time of treatment will ordinarily be shorter; the ultimate requirement being that the times and temperatures of the two heat treatments must be such that the sum total is sufficient to give complete diffusion; that is, so that the zones of stainless steel on each side of the strip extend inward from the surfaces entirely to the other zone.

In the drawing, the steps of Example 1 are shown diagrammatically in Figs. 1 through 5.

Figure 1 illustrates diagrammatically in cross section the steel strip base metal 11, upon which the alternate layers of chromium 12, nickel 13, chromium 14, and nickel 15 are plated on each side;

Fig. 2 illustrates diagrammatically in cross section the plated strip after the first heat treatment, in which there may still be a central zone of steel 11a, intermediate zones of chromium-nickel-iron alloy 16, and outer zones of chromium-nickel alloy 17. It is to be understood that the showing in the drawing is entirely diagrammatic, as there may be some little diffusion of the iron clear out to the outer surface, and some little diffusion of the chromium and nickel entirely into the steel.

Fig. 3 illustrates diagrammatically in cross section the strip of Fig. 2 after it has been reduced to .070" in thickness by the first cold rolling step.

Fig. 4 illustrates diagrammatically in cross section the result of the second heat treatment step by which complete diffusion has been obtained so that the entire strip is a chromium-nickel-iron alloy stainless steel strip 18.

Fig. 5 shows the finished stainless steel strip diagrammatically in cross section after the strip of Fig. 4 has been cold rolled to .040" thick.

Example 2

Other alloying metals may be incorporated in the stainless steel strip made by the present invention by incorporating the alloying metals in the base stock metal. Thus, a higher carbon, manganese stainless steel strip may be made by starting with a base stock steel strip .074" thick containing .47% manganese and .23% carbon. The strip may then be electroplated on each side with a layer of .003565" of nickel followed by an electroplated layer on each side of .01005" of chromium.

The strip is then heat treated at a temperature within the range of 1100° F. to 2500° F. in a reducing or non-oxidizing atmosphere for a sufficient time to give partial diffusion of the plated metals with the base metal and with each other. The strip is then cold rolled to a thickness of .047" thick and reheated in a reducing or non-oxidizing atmosphere at a temperature within the range of 1100° F. to 2500° F. for sufficient time to give complete diffusion and form a homogeneous stainless steel strip containing 18% chromium, 8% nickel, 73½% iron, .35% manganese and .15% carbon.

Example 3

Silicon may also be included in the base stock metal and incorporated in the stainless steel to be made by using as a base stock, strip steel containing say 2.4% silicon, .8% manganese, and 1.13% carbon, the base stock strip steel being

.080" thick. A layer of nickel is then electroplated on each side .001" thick, followed by a layer of chromium on each side .010" thick, followed by electroplated layers on each side respectively of .0015" of nickel and then .010" of chromium.

The strip is then heat treated in a non-oxidizing atmosphere to give partial diffusion of the metals at a temperature within the range of 1100° F. to 2500° F., and is then cold rolled to .050" and reheated for a sufficient time to give complete diffusion of the metals at a temperature within the range of 1100° F. to 2500° F. in a non-oxidizing atmosphere. The strip may then be skin rolled to improve the surface thereof and prevent wrinkles when subsequent forming, stamping or drawing operations are performed. The final strip will be 30.0% chromium, 4.7% nickel, 1.47% silicon, .49% manganese, .693% carbon, and 62.647% iron, with a final thickness of .049 inch.

Example 4

Stainless steel strip containing alloying metals in addition to chromium or nickel or both may also be made by plating alloys of metals rather than individual metals. Thus, a stainless steel strip .010" thick containing 68.81% iron, 18.9% chromium, 7.9% nickel, .36% carbon, .5% manganese, and 3.53% tungsten may be produced by using as a base stock, strip steel .008" thick containing .65% carbon and .90% manganese and electroplating thereon a layer on each side of .0005" of nickel followed by plating a layer .0015" thick on each side of an alloy of 80% iron and 20% tungsten, followed by an electroplated layer on each side of .0015" thick of chromium. The strip is then heat treated in a non-oxidizing atmosphere at a temperature within a range of 1100° F. to 2500° F. to partially alloy the metals, is then cold rolled to a thickness of .012" thick and again heated as aforesaid for a sufficient time to give complete diffusion, and is finally cold rolled to a thickness of .010" thick.

Example 5

More rapid diffusion of the alloying metals may be obtained and complete alloying accomplished in a shorter total heating time if part of the iron is electroplated as a layer or layers between the other layers of plated metals. Thus, in producing a stainless steel strip having approximately the same analysis as that obtained in Example 1, a low carbon steel strip .007" thick may be electroplated on each side with a layer of .001" of nickel, followed by a layer on each side of .0014" of chromium, followed by an electroplated layer on each side of .007" of iron, and finally with a layer on each side of .0014" of chromium.

The strip is then heat treated in a non-oxidizing atmosphere at a temperature within the range of 1100° F. to 2500° F. to obtain partial diffusion; and is then cold rolled to a thickness of say .014". The strip is again heat treated as aforesaid in a non-oxidizing atmosphere to give further diffusion and is then cold rolled to a thickness of .010". The strip is then further heat treated as aforesaid to obtain complete diffusion, and is finally cold rolled to a final gauge of .008" thick; the resulting strip being a stainless steel strip containing approximately 17.9% chromium, approximately 8.02% nickel, and approximately 74.08% iron.

Example 6

A chrome-iron alloy stainless steel strip may

be produced in accordance with the treatment of any of the preceding examples, by electroplating alternate layers of chromium and iron upon base stock in such proportions as to give the desired resulting analysis. The plated base stock is then subjected to alternate heat treating and cold rolling operations as aforesaid to obtain complete diffusion of the plated iron and chromium with each other and with the base stock. At least two heat treatments and at least one cold rolling must be carried out in order to obtain ductility in the final product.

Example 7

Stainless clad strip steel may be produced in a manner similar to that outlined in the foregoing examples for the manufacture of stainless steel, by plating the component metals on the steel strip base stock, and then heat treating and cold rolling to obtain the desired diffusion and finished gauge.

As previously stated, the number and sequence of plating layers may be selected in accordance with the finished product desired, the greater the number of thinner plated layers, the shorter will be the time required for diffusion of the coating metals with each other and consequently diffusion of the coating metals into the base stock will be proportionately less. It is advantageous to electroplate a layer of iron next to the base stock when making stainless clad steel strip in order to reduce diffusion into the base stock during heat treatment.

In producing a stainless clad steel strip in which the stainless steel zones which extend a substantial distance inward from each surface of the finished strip, a steel strip .050" thick is electroplated with a layer of iron .00031" thick (each side), then a layer of nickel .0000875" thick (each side), then a layer of chromium .0002525" thick (each side), and the strip is then heat treated in a non-oxidizing atmosphere at a temperature within the range of 1100° F. to 2500° F., preferably around 1800° F., to obtain partial diffusion of the plated metals with each other. The strip is then cold rolled to a thickness of .040", and after suitable cleaning the strip is again electroplated with a layer of iron .00025" thick (each side), then a layer of nickel .000072" thick (each side), and then a layer of chromium .000202" thick (each side), and again heat treated to a temperature within the range of 1100° F. to 1800° F. to obtain complete diffusion of the electroplated metals. There will also be some diffusion of the non-ferrous plated metals with the base stock, but this will be reduced if the first plated layer is iron.

In this example, if the heat treatment is of sufficient duration to cause the diffusion of the plated layers into the base stock to be a distance of approximately .001" (each side), and if the strip is then cold rolled to a final thickness of .035", the final strip will have a steel base .031" thick with a stainless steel coating thereon .002" thick on each side; the stainless steel coatings having an approximate analysis of 18% chromium, 8% nickel and 74% iron.

The plated layers are preferably made quite thin and increased in number so that the time of heat treatment may be reduced to obtain complete diffusion for forming the desired stainless alloy in zones extending inward a substantial distance from each surface of the strip. Moreover, heat treating and cold rolling may be interposed between plating steps, as previously described in

connection with the manufacture of stainless steel strip.

In the drawing, the steps of Example 9 are shown diagrammatically in Figs. 6 through 11.

Fig. 6 illustrates diagrammatically in cross section the strip steel base metal 21, upon which the alternate layers of iron 22, nickel 23, and chromium 24 are electroplated on each side.

Fig. 7 illustrates diagrammatically in cross section the plated strip after the first heat treatment, in which there is a central zone of steel 21a, and also zones 28 extending inward a substantial distance from each surface composed of the plated metals 22 to 24, which have been partially alloyed with each other and with the adjacent base metal.

Fig. 8 illustrates diagrammatically in cross section the strip of Fig. 7 after it has been materially reduced in thickness by the first cold rolling step.

Fig. 9 illustrates diagrammatically in cross section a strip of Fig. 8 after additional layers of iron 25, nickel 26, and chromium 27 have been electroplated thereon.

Fig. 10 illustrates diagrammatically in cross section the result of the second heat treatment step by which complete diffusion of the plated metals has been obtained, so that there are zones extending inward from each surface of the strip a substantial distance, composed of chromium-nickel-iron alloy 36 on the base metal 21a.

Fig. 11 shows the finished stainless clad steel strip diagrammatically in cross section after the strip of Fig. 10 has been further cold rolled.

Example 8

In making thin gauge strip with a very thin stainless steel coating on each side thereof, a low carbon steel strip .015" thick is electroplated on each side with a layer of iron .00000614" thick, then on each side with a layer of nickel .00000051" thick, and then on each side with a layer of chromium .000001554" thick. The plated strip is then heat treated in a non-oxidizing atmosphere as aforesaid to obtain partial diffusion of the plated metals with each other. The strip is then cold rolled to a thickness of .02025", and is again heat treated to obtain complete diffusion, and is finally skin rolled to a thickness of .010". The resulting stainless clad steel strip is composed of a steel base slightly less than .010" thick with stainless steel cladding on each side .0000055" thick. This cladding will have an approximate analysis of 17% chromium, 7% nickel and 76% iron.

Example 9

An even thinner strip may be made with a thin stainless steel cladding on one side thereof by plating a low carbon steel strip, say .001" thick on one side with a layer of .0002" of iron, then with a layer on said side of .00003" of nickel, and then with a layer on said side of .0001" of chromium, the other side of the strip being shielded to prevent electroplating thereon. The strip is then heat treated to effect substantially complete diffusion of the plated layers, and said side is again electroplated with a layer of .0002" of iron followed by a layer of .00003" of nickel, and finally with a layer of .0001" of chromium. The strip is again heat treated as aforesaid to obtain complete diffusion of the coating metals with each other, and is finally cold rolled to a thickness of .001", so that the steel strip is slightly less than .001" thick with a cladding on one side of .0004" of stainless steel having an approximate analysis

of 27.96% chromium, 10.43% nickel, and 61.61% iron.

In making the cladding on only one side, the shielding of the other side during electroplating may be accomplished in any well known way so as to prevent throwing of the plated metals around the edges of the strip.

Example 10

The fundamental procedure of Example 13 may be carried out to obtain one analysis of cladding on one side of the strip, and a different analysis of cladding on the other side of the strip by electroplating a low carbon steel strip .030" thick on one side with .00202" of iron, then .00025" of chromium, then .00202" of iron, and then .00025" of chromium; after which the other side of the strip is plated with .00052" of copper, then with .001" of nickel, then with .00052" of copper, and then with .001" of nickel. The strip is then heat treated as aforesaid to obtain partial diffusion of the plated metals with each other and is then cold rolled to a thickness of .025". Thereafter the strip is further heat treated to completely diffuse the plated metals with each other, the final strip being .025" thick with stainless steel cladding on one side .003" thick having an approximate analysis of 10% chromium and 90% iron, and with a cladding on the other side of .002" of monel metal having an approximate analysis of 65% nickel and 35% copper.

In general

Although no example has been given of the thickest base stock which may be used, the base stock may be up to say .375" thick, and may be as thin as .001" thick as in Example 9. Both stainless steel and stainless clad steel strips may be made with a final thickness after plating, heat treating and cold rolling of .375" thick to .001" thick. The limits of total thickness of metals plated on the strips to make clad strip may be from .0000055" to .035".

The more important advantages of the processes comprising the present invention are that a relatively cheap steel base strip stock may be used as a starting or raw material, and other metals, some of which may be expensive metals, can be added in accurately controlled amounts by electrodeposition. Stainless steel strip, particularly of the thinner gauges, and also stainless clad strip can be produced at a much lower cost of production than when these materials are made in accordance with conventional practice; and the resulting products may be severely deep drawn, stamped or formed.

A further advantage of the present invention is that while it is difficult and expensive to make low carbon stainless steel such as .06% to .08% carbon stainless steel, it is relatively easy to make such a low carbon common steel which can be used as a base stock in the present invention for readily, easily and cheaply making such a low carbon stainless steel.

In carrying out the invention, the alternate heat treatment and cold rolling changes the relatively brittle electrodeposited layers of metal into ductile alloys. If the plated strip were cold reduced without heat treatment, strains would be set up, which would eventually cause the layers to separate from the base stock; and the heat treatment removes these strains and permits further cold reduction without danger of cracking. Each successive heat treatment and cold rolling increases the ductility of the stock, and when

sufficient alloying and cold working is applied, the resulting product can be drawn, stamped, or formed without destroying the rust-resisting properties of the metal.

The cold rolling or working also smooths the plated metals, makes a more uniform product, reduces porosity, and elongates surface grains; and the final surface of the product may be controlled by the final cold rolling operation.

Moreover, the number of alternate heat treatments and cold rolling, and the time and temperature thereof, is determined by the thickness of the coating layers and qualities desired in the final product; and because the number and thickness of the coating layers may be controlled, the resulting composition can be controlled or varied at will, so that the process is very flexible for producing any desired composition of stainless or stainless clad steel strip and the like.

Whenever the term "heat treatment" is used herein and in the appended claims, it means a heating operation carried out in either a non-oxidizing or a reducing atmosphere, or a heating operation carried out under conditions which may be oxidizing, followed by a pickling operation to remove any scale produced. In other words, any heat treating operation called for herein must be accompanied by the prevention or removal of oxides.

The term "cold rolling" when used herein and in the appended claims, is intended to include a cold rolling, a cold working, a skin rolling, or cold drawing operation. Whenever the word "strips" or the words "strips and the like" are used herein, the same are intended to include products such as strips, strip-sheets, sheets, or wire.

The words "strips of the thinner gauges" as used herein, are intended to include strip products and the like having gauges as thin as .001 inch.

The term "low carbon steel" as used herein and in the appended claims is a usual term used in the art and means a steel containing up to about .12% carbon.

I claim:

1. The method of making ductile stainless and stainless clad rolled steel strips, which consists in electroplating layers of chromium and nickel upon a low carbon rolled steel strip base in the required proportions to give the desired stainless steel analysis in the finished product, and then subjecting the plated base stock to at least two heat treating and at least one cold rolling operations between said heat treatments, said heat treating operations being conducted at temperatures between 1100° F. and 2500° F. and below the melting points of the metals but sufficiently high to completely diffuse the chromium and nickel with each other and at least partially diffuse them with the base stock.

2. The method of making ductile stainless and stainless clad rolled steel strips, which consists in electroplating layers of chromium and iron upon a low carbon rolled steel strip base in the required proportions to give the desired stainless steel analysis in the finished product, and then subjecting the plated base stock to at least two heat treating and at least one cold rolling operations between said heat treatments, said heat treating operations being conducted at temperatures between 1100° F. and 2500° F. and below the melting points of the metals but sufficiently high to completely diffuse the chromium and iron with each other and at least partially diffuse them with the base stock.

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3. The method of making ductile stainless and stainless clad rolled steel strips, which consists in electroplating upon a low carbon rolled steel strip base layers of metals consisting of chromium and a metal of the group consisting of iron and nickel, said metals being in the required proportions to give the desired stainless steel analysis in the finished product, and then subjecting the plated base stock to at least two heat treating and one cold rolling operations between said heat treatments, said heat treating operations being conducted at temperatures between 1100° F. and 2500° F. and below the melting points of the metals but sufficiently high to completely diffuse the plated metals with each other and at least partially diffuse the plated metals with the base stock.

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4. The method of making ductile stainless and stainless clad rolled steel strips, which consists in electroplating upon a low carbon rolled steel strip base layers of chromium, iron and nickel, said metals being in the required proportions to give the desired stainless steel analysis in the finished product, and then subjecting the plated base stock to at least two heat treating and one intermediate cold rolling operations to completely diffuse the plated metals with each other and at least partially diffuse the plated metals with the base stock, and performing the heat treating operations at temperatures within the range of 1100° F. to 2500° F.

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