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PRODUCTION OF COATED SOFT IRON AND STEEL SHEETS

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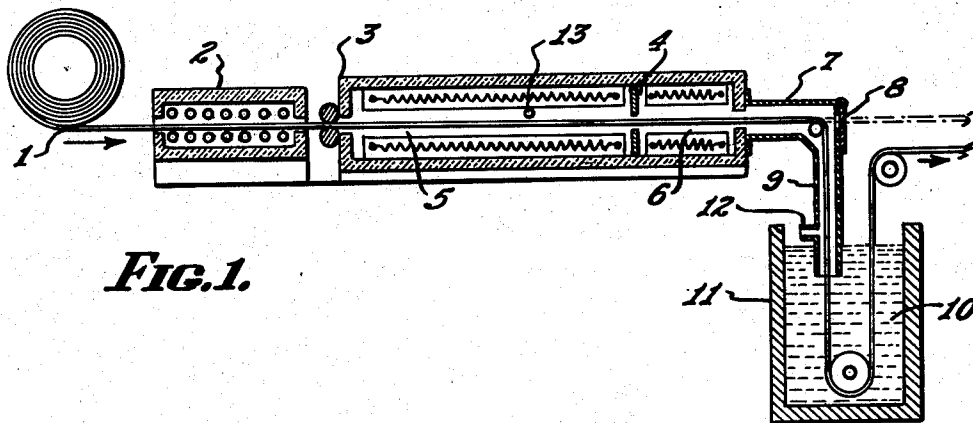


FIG. 1.

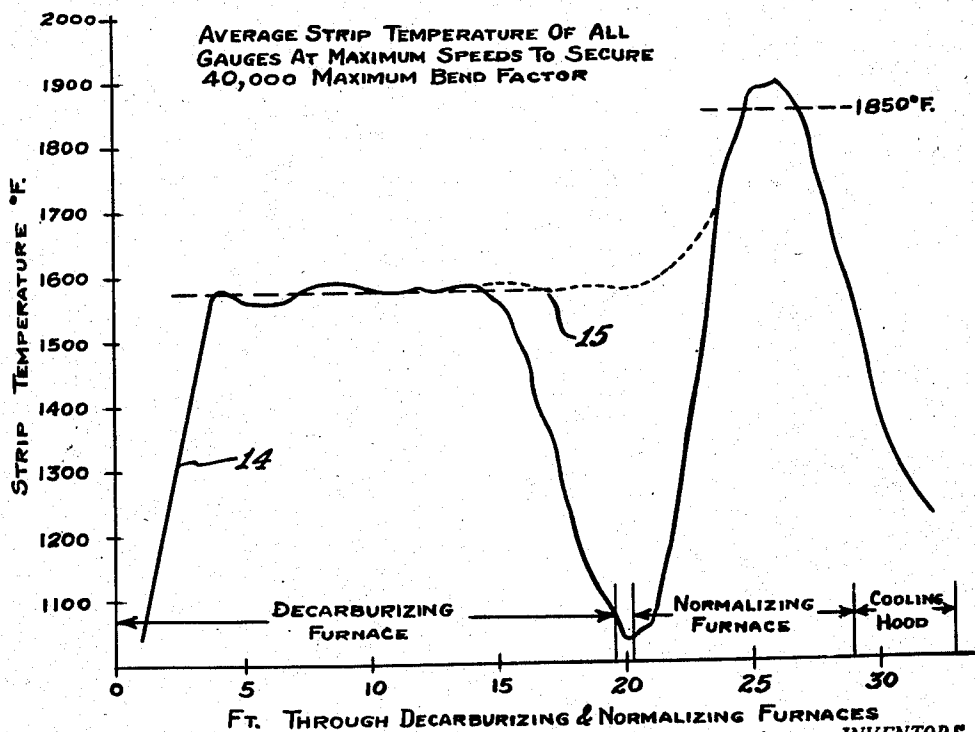


FIG. 2.

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PRODUCTION OF COATED SOFT IRON AND
STEEL SHEETSRobert S. Burns and Robert L. Solter, Middle-
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The principal object of our invention is the provision of a rapid and inexpensive process whereby soft iron and steel sheet stock may be produced from materials which have been cold reduced.

It is an object of the invention to produce from cold reduced iron or mild steel in a rapid and inexpensive manner a sheet stock which has a softness the equivalent of "soft merchant sheets" produced by hot rolling and annealing processes.

It is an object of our invention to provide a process for softening iron or mild steel sheet stock which does not itself involve a rolling, or a critical straining and annealing procedure, and which may be applied to the sheet stock after it has been reduced to gauge and is otherwise finished.

It is an object of our invention to provide a softening procedure which may be carried on as an incident to other operations, as will herein-
after be set forth.

It is an object of our invention to provide a mode of softening which may be practiced either separately or as a part of a process of hot coating the sheet stock with protective metals.

Novel products are produced by our procedures; and the making of these products constitutes an object of the invention.

These and other objects which will be set forth hereinafter or will be apparent to one skilled in the art upon reading these specifications, we accomplish by those procedures and modes of operation, and in those products of which we will now describe exemplary embodiments. Reference is made to the accompanying drawing wherein:

Figure 1 is a diagrammatic representation of an assembly of apparatus with which our process may be carried on, this apparatus including means for coating the treated sheet stock with a molten protective metal.

Figure 2 is a curve showing exemplary temperature conditions obtaining throughout our softening treatment.

By "iron or mild steel" we mean any of those ferrous materials classified under these terms in the standard literature, and in particular ferrous materials containing less than about 0.25 percent of any one alloying ingredient, except manganese which may be as high as .60%. Such materials, as produced by the best modern methods, usually contain carbon of the order of .02%-.10% although this may vary considerably depending upon the source of the ferrous material. The presence of other alloying ingredients is not a limitation on the invention. By "sheet stock" we mean a ferrous material of sheet thickness, whether existing in the form of individual sheets, or in the form of a continuous strip, regardless of width. Our process is applicable to individual sheets; but is most conveniently carried on with the stock in the form of a continuous strip, since

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under these circumstances better control is possible. By "cold rolled stock" we mean a ferrous material which, from an intermediate gauge to which it was hot rolled or otherwise reduced, has been reduced to final sheet gauge by a substantial cold reduction as distinguished from a mere temper rolling. No specific amount of cold reduction performed on the material prior to the application of our processing steps forms a limitation on the invention. Furthermore our procedure is applicable to material which has not been cold reduced at all.

Before the advent of modern cold mill processing, soft steel sheets were made by hot rolling on hand finishing mills, and then box annealing the product. This gave a very soft sheet, suitable for bending without springback, i. e. it was readily formable and was known in the trade as a "soft merchant sheet." Such sheets were widely used in the galvanized condition. Where an extremely soft condition was not required, hot rolled sheets in the old art were frequently normalized instead of being box annealed.

Hot rolling followed by box annealing produced sheets having 30,000 to 40,000 p. s. i. bend factor and a Rockwell "B" hardness of 30 to 45. In recent times the old hot mill procedures have largely been supplanted by more economical cold reduction processes. Bend factors of 45,000 to 65,000 p. s. i. and Rockwell "B" hardness of 45 to 60 are those conventionally obtained from cold reduced stocks with any of the usual commercial after-treatments, i. e. whether the sheet stocks were normalized only, box annealed only, or both normalized and box annealed. The interruption of the cold reduction for an intermediate anneal, and the use of a final box anneal after the cold reduction will give a greater softness than indicated by the last figures above, but is economically unsound because of the expense involved. Hence there has not hitherto been provided any commercially feasible way of obtaining cold reduced sheets approximating the formability and softness characteristic of the old hot rolled "soft merchant sheets" at a price comparable to the price of ordinary cold rolled steel.

It is within the scope of our invention, however, not to carry the softening process so far as to produce the degree of softness of the "soft merchant sheet." Our invention provides an inexpensive and rapid way of softening cold rolled materials; and may be practiced to any extent desired depending upon the qualities desired in the final product. It will be understood of course that the cold rolling and finishing procedures current in the art have produced iron and mild steel stocks of excellent drawability, substantial hardness, and a fine grained condition. Hence the utility of our process is primarily realized where a larger grained and softer condition is desired, and where improved bending or forming characteristics are

desired, possibly at some sacrifice of drawability.

We have discovered that if iron or mild steel sheet stock is decarburized to the extent of lowering the carbon content to values such as herein-after set forth, the result of a subsequent heat treatment in which the temperature of the material is raised above its A_3 point will be the opposite of the result obtained from a normalizing treatment performed on conventional material. Instead of recrystallizing upon cooling with a fine grain structure and considerable stiffness, the material develops a coarse grain structure and a substantial softness. The decarburizing step, which is a heat treatment, and the step of heating of the material to above its A_3 point, and its subsequent cooling, may be practiced very rapidly and with relatively inexpensive equipment. The heat treatments may be carried on after the manner of strand or continuous anneals, i. e. with individual sheets or a strip of material passing through an elongated furnace in which all surfaces of the material are "open" to the atmosphere of the furnace. Both these treatments may be carried on, if desired, in a single strand type furnace, preferably one in which different zones may be segregated by baffles or the like. Both these treatments may be practiced upon materials of final sheet thickness; and the time durations of the treatments are short. The sheet itself need only be in a reasonably clean condition, i. e. free of scale, though not necessarily free of oxidation, and may be freed of coatings of oil and grease prior to or as an incident of the process.

As a consequence, ordinary cold rolled stock is suitable for use in our procedure usually without other pre-treatment than a simple de-greasing. This may be accomplished in various ways, as by chemical or electrochemical cleaning, but is most cheaply accomplished by passing the stock through a flame or a short furnace in which it is heated to around 650° F. to 800° F. in an air atmosphere in which the oils and greases are burned from the surface of the stock. The decarburizing treatment hereinafter described will, as a matter of fact, remove oils and greases from the surface of the stock; but carbonaceous residues from these materials are likely to be left in the furnace and to cause operating troubles. Hence we prefer to de-grease the stock prior to decarburization.

It may be noted that our procedure may be practiced upon cold reduced stock which has already been annealed; but it is also capable of serving as an annealing treatment in itself. Thus our procedure may be practiced upon cold rolled strips or sheets which have neither been box annealed nor normalized, following the final cold rolling.

For the decarburizing step of our process, we prefer to pass the sheet stock through a strand or open annealing furnace containing a wet, hydrogen bearing atmosphere. The object of this step is to reduce the carbon content of the sheet, as later described without producing excessive oxidation. It is desirable to have hydrogen present primarily to prevent excessive oxidation of iron, and the quantity of hydrogen may vary (and will vary with the source of the atmosphere) roughly between 5% and 100%. Its effect will vary with variations of temperature and time. Other reducing gases, such as carbon monoxide, may be used in the place of some or all of the hydrogen. In this event some hydrogen may be

produced by reaction between the carbon monoxide and the moisture. Other gases besides water vapor may supply the oxygen in the active form necessary to bring about the decarburizing action. Carbon dioxide, for example, will produce satisfactory decarburization, especially when used in the correct ratio with carbon monoxide to prevent excessive oxidation, which can readily be calculated from well known equilibrium data. The active gases can be diluted with inert gases such as nitrogen without affecting the decarburizing action except for generally slowing down the rate of the reaction as the active gases become more dilute.

Our preference for water vapor for the major decarburizing medium is based upon its being in general more rapid in its action. Moreover, it is possible to use combinations of oxidizing gases such as water vapor and carbon dioxide together with hydrogen and carbon monoxide.

The minimum water vapor content, or minimum dew point in our preferred method is that which will decarburize (in our sense) in the chosen short length of time; the maximum which can be added to a particular atmosphere is that which will decarburize without producing undesired oxidation. We prefer to decarburize under conditions which are strongly oxidizing to carbon but at the same time reducing to iron, at temperatures below the A_3 point of the material being treated, and to effect the decarburization in a very brief length of time. Hence our preference for a wet atmosphere containing a gas which will be reducing to iron at the temperatures involved.

By way of example, with dissociated ammonia (about 75% hydrogen, balance nitrogen) we employ a dew point between 110° and 170° F. with a preferred range of 130° to 150° F. The temperatures of the heat treatment will lie between 1300° and 1650° F. with a preferred range of 150° to 1600° F. For other atmospheres containing larger or smaller amounts of reducing gas, it will be within the skill of the practitioner to vary the water content to avoid undesired oxidation.

Under conditions such as outlined above, the time required in our process is of the order of one to ten minutes and therefore is well within the commercial possibilities of open annealing furnaces and open annealing treatments.

Principal advantages of our process are that in a single continuous furnace or pair of continuous furnaces as herein described, a very rapid treatment may be carried on involving decarburizing at a temperature below the A_3 point and a brief recrystallization produced by heating the metal above that point. We have found that by the methods taught herein, within the span usually of two or three minutes, the carbon content of ordinary iron or mild steel may be reduced dependably to .01% or less, and that reductions of carbon content obtained in this way will be effective upon subsequently heating the metal to above its A_3 point to produce a very substantial softening of the metal accompanied by a very substantial grain growth.

For the final heat treatment, in a segregated portion of the same furnace, or in a separate furnace, we heat the sheet stock to a temperature above about 1700° F. "Normalizing" is defined in Metals Handbook as a heating to approximately 100° F. above the critical temperature range, followed by a cooling in still air. The procedure we follow in the second heat treatment step of our process is not so strictly limited, it being necessary only to heat the metal to a

temperature above its A_3 point, and hold it there for a short period of time, whereupon it may be cooled at any rate desired. This is preferably done in a protective atmosphere which may either be neutral, or reducing, e. g. a dry, hydrogen-bearing atmosphere, and the cooling is also preferably carried out in such an atmosphere to prevent oxidation as the temperature falls. The cooling is preferably more rapid than cooling in still air, to save time on a continuous apparatus.

Referring to Figure 1 herein, we have indicated a metal strip 1 as the material subjected to our process. It is a cold reduced strip and will normally have an oiled surface. While we may clean it in other ways as indicated above, we prefer to pass it first through a short oxidizing furnace 2 wherein we heat it and burn the oil from its surfaces. Open flames may be employed if desired.

The formation of a light temper-color oxide on the strip is not detrimental, provided it is not permitted to become so heavy that it will not be reduced in the subsequent furnaces. In some cases where the strip is to be given a metallic coating, such thin oxide coating is desirable.

The strip next passes to a furnace indicated generally at 3. This furnace is divided into two parts as by baffles or the like as indicated at 4. The first and longer portion of the furnace is that in which the decarburizing step takes place. This portion of the furnace is indicated at 5. In it will be maintained a (preferably) hydrogen bearing atmosphere which is wet as set forth above. The hydrogen bearing atmosphere may be derived from any suitable source. Cracked ammonia is a relatively inexpensive source, and one which is entirely suitable, providing the amount of undissociated ammonia in the atmosphere is kept low. As indicated above, pure hydrogen may be used, or any atmosphere (e. g. DX gas, a partially burned hydrocarbon gas) containing sufficient hydrogen to prevent undesired oxidation with quantities of moisture effective for rapid decarburization. The balance of the atmosphere is preferably inert gas such as nitrogen but may contain minor amounts of carbonaceous gases provided the combination is not carburizing to iron in accordance with well known equilibrium data.

Hydrogen may, in fact, be omitted altogether, and decarburization secured through the effects of water vapor in an otherwise inert atmosphere, but inasmuch as relatively heavy surface oxidation is likely to occur under these conditions a pickling or cleaning treatment would be added to the process, which we prefer to avoid. Nevertheless a sufficient decarburization at this stage will be productive of the softness after the metal is subsequently heated above its A_3 point as taught herein.

The second portion of the furnace is that indicated at 6, and is the portion in which the metal is heated above its A_3 point. A second or separate furnace may be employed if desired; but there is no advantage in cooling the material between the furnaces, unless some additional treatment, as a pickling, is to be practiced at this point. It is, of course, possible to carry out our process using entirely separate decarburization and subsequent heating furnaces, the separation being both in space and time. The economical advantages are with the continuous process. If separate furnaces are used in a continuous process, it is preferable to locate them

closely adjacent to each other so as to minimize cooling and oxidation of the piece between the furnaces.

In Figure 1, we have shown the furnace portion 6 as provided with a cooling hood 7 communicating with it. This cooling hood may be provided with a closable port 8 permitting the direct removal of the treated strip. It is shown as provided also with a downwardly extending portion 9 dipping beneath the surface of a bath of molten coating metal 10 in a coating pot 11. The hood and the furnace portion 6 are kept filled with a neutral or reducing atmosphere, as set forth above.

A dry, hydrogen-bearing atmosphere may, for example, be introduced into the cooling hood portion 9 through a port 12, and caused to pass through the furnace portions in countercurrent to the metal strip. The atmosphere will be dry in the cooling hood and in the furnace portion 6; and its humidity may be raised in the decarburizing portion 5 by admission of steam as through a port or ports 13, although other methods of adding moisture may be employed, such as the addition of drops of water which will vaporize at the temperature of the furnace. If the two furnace portions are separate, the atmosphere in the decarburizing portion may be wetted by bubbling it through water, or otherwise.

Our preferred mode of operation is one wherein the two furnace portions are connected, where the decarburization is so accomplished as to leave the sheet surfaces very lightly oxidized if at all, and with the production at most of only a light temper color on the iron or steel, and where the atmosphere in the higher temperature portion not only protects the sheets from oxidation but insures the reduction of any oxide of iron on their surfaces.

If separate furnaces are employed for the portions 5 and 6, and some oxidation and drop in temperature occurs between them, the length of the furnace portion 6 may be increased in order to provide a sufficient length of time for reheating and reduction. Between such separate furnaces it is sometimes desirable to introduce a strip cleaning means, such as, for example, an oxidizing furnace like furnace 2. However where the furnace portions 5 and 6 are part of the same apparatus and are connected as shown, the strip will ordinarily be received in a clean and oxide-free condition from the furnace portion 5, and the furnace portion 6 may be relatively short.

The total overall length of the furnace portions will be chosen in relation to the speed of travel of the materials therethrough, in order to obtain the required time durations for the heat treatments. From the figures hereinafter given, it will be seen that a ratio of lengths of the decarburizing furnace portion to the higher temperature furnace portion of $3\frac{1}{2}$ to 1 is a satisfactory operating length ratio for materials having an initial carbon content of around 0.20%.

In order to make an exemplary showing herein, we give complete data for a commercial ingot iron of the following analysis:

	Percent
Carbon	.02
Manganese	.02
Phosphorus	.006
Sulphur	.021
Silicon	Trace

This composition is not limiting, but is typical of advantageous compositions because of its initially low carbon content. Sheet stock was rolled from the iron in thicknesses of .015, .020, .025 and .030 inches as covering a general commercial range of sheet stock thicknesses. Data is given for the treatment of each thickness.

The "bend factor" is the maximum fiber stress at the point of yielding produced by simple bending and is measured in pounds per square inch. The "bend factor" test is conducted by loading a sheet specimen (1 $\frac{3}{4}$ " $\times$ 3 $\frac{1}{2}$ "') as a simply loaded beam, the load applied at the end supports reacting against the fulcrum of a load indicator at the center. The sample exhibits a permanent set after testing. The apparatus and method of making the test are described in Patent No. 1,745,634.

The Rockwell hardnesses are determined by the A. S. T. M. procedure. The grain size figures are in accordance with the A. S. T. M. standard. The decarburizing was carried on at 1575° F. in a dissociated ammonia atmosphere containing water vapor and having a dew point of 135° to 145° F. Heating to above the A₃ point was carried on at a temperature of 1850° F. in an atmosphere of dry, dissociated ammonia.

The furnaces may be heated in any desired way, consistent with the maintenance of the required atmosphere. We prefer either to heat the furnace sections electrically or to use gas fired radiant tubes.

In Table No. 1 we first show decarburizing times for the various thicknesses of the ingot iron, which, coupled with subsequent heating times as shown, give a grain growth sufficient to reduce the bend factor to a maximum of 40,000 p. s. i. Next we show the time required to effect the maximum possible decarburization of the iron without producing brittleness in it. This is a characteristic of iron having such low manganese content and can be disregarded for mild steels, which may be decarburized to any extent desired without becoming brittle. These latter times of decarburization, with the subsequent heating times indicated, lower the bend factor to between 31,000 and 36,000 p. s. i. The times indicated for the subsequent heat treatment are the same in both instances, and are those which give desired grain growth. An increase in time up to 10 minutes, as well as an increase in the temperature from 1850° to 1925° F. did not further improve the bend factor. The times given are in all instances those for the maintenance of the strip at temperature. If the equipment is so constructed that there are areas in which the temperature of the strip is not maintained, this must be taken into account.

TABLE 1

Thickness	Time to decarburize for 40,000 p. s. i. max. bend factor, min.	Time for max. decarburization, bend factor 31,000-36,000 p. s. i. min.	Subsequent heating, min.
0.015 in.	1.4	2.8	0.4
0.020 in.	1.9	3.2	0.5
0.025 in.	2.1	3.5	0.6
0.030 in.	2.4	4.2	0.7

Insufficient decarburization is indicated by carbon in excess of the following values:

TABLE 2

Thickness	For 40,000 p. s. i. Max. B. F.	For Min. Bend Factor (31,000-36,000) p. s. i.
0.015 in.	0.011% C	0.006-0.007% C
0.020 in.	0.010% C	0.006-0.007% C
0.025 in.	0.009% C	0.006-0.007% C
0.030 in.	0.009% C	0.006-0.007% C

An insufficient or improper final heating is indicated by failure of the material to develop coarse grains in spite of a suitably low carbon content.

In the following table we correlate bend factors, grain size, and final carbon contents for a number of samples of material .020 inch in thickness.

TABLE 3

Sample No.	Carbon after Decarburization, percent	ASTM Grain Size After Subsequent Heating	Average Bend Factor p. s. i.
1	.006	1 and 2	34,000
2	.007	2 to 4	37,000
3	.009	2 surface, 5 and 6 midthickness	38,000
4	.010	4 surface, 6 midthickness	40,000
5	.012	5 surface, 7 midthickness	43,000

We show below a table of mechanical properties of material of the above analysis giving figures for mechanical properties representative of three degrees of decarburization. These figures illustrate mechanical properties to be expected at the carbon content obtained for each degree of decarburization.

TABLE 4

Mechanical properties of decarburized and subsequently heated ingot iron

Degree of Decarburization	Percent Carbon	Bend Factor, p. s. i.	Rockwell "B"
1	.006	30,000	30
2	.009	40,000	45
3	.012	43,000	48

Figure 2 shows typical but non-limiting temperature conditions during the carrying on of our process. Strip temperature is plotted against the length of the furnace and cooling hood areas, which of course is a measure of time at any given strip speed. The solid line 14 is indicative of temperature conditions where separate furnaces are used for decarburizing and for the subsequent heating but where these furnaces are closely juxtaposed. If a continuous, baffled furnace as illustrated in Figure 1 is employed, the strip may follow the same general temperature conditions, without the intermediate lowering of temperature between the furnaces. Instead, the strip temperature will follow at this portion the dotted curve 15, or an approximation to it.

The initial carbon content of the cold rolled strip or sheets will have an effect upon the time for decarburization to the value set forth; the higher carbons taking the longer times. For this reason we prefer to use low carbon material such as ingot iron, which is relatively inexpensive and decarburizes quickly. Mild steel can be used, however, except that a somewhat longer decarburizing time is required because of its higher carbon content, which commonly is 0.04% or higher.

Since the time duration of the heat treatment above the A₃ point is short, inasmuch as it is

only necessary to hold the strip at the required temperature for a length of time at least as long as indicated above, the speed of travel of the strip in any given apparatus may usually be regulated for the decarburizing treatment.

Our process is useful for the general softening of cold rolled iron and mild steel stock of sheet gauge, as has been indicated. It is also useful for a number of special purposes. For example, reference is made to the Sendzimir Patents No. 2,136,957 and No. 2,197,622 having to do with the hot coating of metal strip or articles. In Figure 1 of this application we have shown and described a furnace mechanism terminating in a cooling hood with a bell leading to a point beneath a bath of molten coating metal. In the Sendzimir patents, a process of hot coating is described, resulting in exceptional adherence of the coating. In the use of the mechanism illustrated in our Figure 1, the same effect is secured and by the same metallurgical phenomena, although other phenomena are present resulting in an unusual softness of the base material, as has been described.

Prior practice of the Sendzimir process has heretofore resulted in a relatively stiff sheet, because of the grain refining action of the final heat treatment in the reducing furnace and cooling zone, although the adherence of the coating, especially when of zinc to which a minor quantity of aluminum is added, has been excellent.

By the practice of our process, we can make the base metal, albeit the base metal is a cold rolled product, as soft and easily formable as a "soft merchant sheet" made by hot rolling and annealing; and in the practice of our invention we have produced for the first time such an iron or mild steel sheet stock which is very soft and easily formable with low springback in combination with a galvanized coating which is strongly adherent and of sufficient ductility to take without peeling or flaking all of the bends which the base metal is capable of withstanding.

An excellent product may be made by treating iron or mild steel stock in accordance with the teachings above and coating it with aluminum in accordance with the Sendzimir method.

Modifications may be made in our invention without departing from the spirit of it. Having thus described our invention in an exemplary embodiment, what we claim as new and desire to secure by Letters Patent is:

1. A process of softening cold reduced iron or mild steel sheet stock which comprises subjecting said stock to a strand anneal in an elongated furnace with two successive portions separated by baffles, introducing into said furnace in counter-current to the stock passing therethrough a dry, hydrogen-bearing atmosphere, which fills the final portion of said furnace beyond said baffles, introducing moisture into the initial portion of said furnace ahead of said baffles whereby to bring the hydrogen-bearing atmosphere therein to a dew point of substantially 110° to 170° F., maintaining the said forward portion of said furnace at a temperature between substantially 1300 to 1650° F., maintaining the final portion of said furnace at a temperature above substantially 1700° F., cooling said stock from the temperature of the final portion of said furnace in a hood connected therewith and supplied with said dry hydrogen-bearing atmosphere, and, without re-exposing said stock to the external atmosphere, passing it beneath the surface of a molten coating metal.

2. A process of softening cold rolled iron or mild steel sheet stock which comprises subjecting said stock to a strand anneal in an elongated furnace with two successive portions separated by baffles, introducing into said furnace in counter-current to the stock passing therethrough a dry, hydrogen-bearing atmosphere, which fills the final portions of said furnace beyond said baffles, introducing moisture into the initial portion of said furnace ahead of said baffles whereby to bring the hydrogen-bearing atmosphere therein to a dew point of substantially 110° to 170° F., maintaining the said forward portion of said furnace at a temperature between substantially 1300 to 1650° F., maintaining the final portion of said furnace at a temperature above substantially 1700° F., cooling said stock from the temperature of the final portion of said furnace in a hood connected therewith and supplied with said dry hydrogen-bearing atmosphere, and without re-exposing said stock to the external atmosphere, passing it beneath the surface of a molten coating metal, which molten coating metal is zinc containing a small quantity of aluminum.

3. The process of claim 2 including the initial step of subjecting the stock to heat under oxidizing conditions to burn grease and oil from its surfaces and form thereon a thin, uniform oxide coating.

4. The process of claim 2 in which the stock, before entering said furnace is cleaned, and its surfaces are provided with a thin, reducible oxide layer.

5. A process of treating cold reduced iron or mild steel sheet stock which comprises forming upon the surfaces thereof a thin coating of oxide of the ordinary thickness of a temper color, thereafter heat treating the stock in a strand annealing treatment in a wet decarburizing atmosphere at a temperature below its A₃ point to reduce the carbon therein to a value not greater than substantially .01 per cent, subjecting the stock to a strand annealing treatment in a dry reducing atmosphere whereby to reduce any oxide on its surfaces at a temperature above the A₃ point whereby to cause a substantial grain growth and substantial softening, cooling said stock, and finally passing the stock beneath the surface of a molten coating metal without re-exposing it to the external atmosphere.

6. A process of softening and coating cold reduced iron or mild steel sheet stock which comprises subjecting said stock to a strand anneal in a wet hydrogen-bearing atmosphere having a dew point of substantially 130° to 150° F. at a temperature of substantially 1500° to 1600° F. and thereafter raising the temperature of said stock to above 1700° F. in said strand annealing treatment, in a dry, hydrogen-bearing atmosphere, cooling said stock, and thereafter leading said stock beneath the surface of a bath of molten coating metal without re-exposing it to air.

7. A process of softening and coating cold reduced iron or mild steel sheet stock which comprises subjecting said stock to a strand anneal in a furnace at a temperature between substantially 1300 and 1650° F. in a reducing decarburizing atmosphere having a dew point of substantially 110 to 170° F., and thereafter raising the temperature of said stock to above 1700° F. in a strand annealing treatment in a dry hydrogen-bearing atmosphere, cooling said stock, and thereafter leading said stock beneath the surface of a bath of molten coating metal while still surrounded by a non-oxidizing atmosphere.

8. A process of treating cold reduced iron or mild steel sheet stock which comprises forming upon the surfaces thereof a thin reducible oxide layer, thereafter heat treating the stock in a strand annealing treatment in a wet decarburizing atmosphere at a temperature below its A₃ point to reduce the carbon therein to a value not greater than substantially .01%, subjecting the stock to a strand annealing treatment in a dry reducing atmosphere whereby to reduce any oxide on its surfaces at a temperature above the A₃ point whereby to cause a substantial grain growth and substantial softening, cooling said stock, and finally passing the stock beneath the surface of a molten coating metal without re-exposing it to the external atmosphere.

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