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METHOD OF MANUFACTURING DRAWING STEEL

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This invention relates to the manufacture of iron or steel materials in sheet thickness and designed for drawing. Its principal object is the provision of modes of manufacture resulting in the avoidance of certain difficulties in present day drawing products, and in a lessening of the over-all cost of the products.

It is an object of the invention to provide a way of making a product having excellent drawing qualities from rimming steel.

Another object of the invention is the manufacture of non-aging sheets from rimming steel.

It is an object of the invention to provide a less expensive routing for the production of non-aging drawing steel.

It is an object of the invention to provide a way of making a better non-aging steel irrespective of whether the metal itself is killed or rimming.

These and other objects of the invention, which will be set forth hereinafter or will be apparent to the skilled worker in the art in the light of the explanations which follow, are attained by that procedure of which certain exemplary embodiments will hereinafter be described.

It has long been understood that one of the qualities desired in a strip or sheet of iron or mild steel intended for drawing is a non-aging quality, i.e. freedom from a definite yield point and freedom from a tendency upon aging to redevelop a definite yield point. In U.S. Patent No. 2,069,758 the manufacture of non-aging drawing stock was taught involving the addition of aluminum, titanium or the like to the molten metal in the ladle in sufficient amounts to degasify the metal and to leave in the metal a small amount of residual degasifier.

It will be obvious that the result is a killed iron or steel. Carbon and also aluminum nitride will have been precipitated from solid solution during a box annealing operation following the cold reduction of previously hot reduced killed iron or steel strip. The product has presented certain disadvantages because of the likelihood of seams, scabs, and on occasion, low yields resulting from the aluminum or titanium killing.

It has now long been known that carbon and nitrogen play principal roles in the aging of ferrous metals. For example, Gensamer and Low, as set forth in their article entitled "Aging and the Yield Point in Steel," Technical Publication No. 1644 of the American Institute of Mining and Metallurgical Engineers, identified carbon and nitrogen as being the chief agents in the aging phenomenon as long ago as 1943, and even suggested, among other things, that an anneal in wet hydrogen could remove both agents.

Nevertheless, no satisfactory or commercially feasible way of producing a rimming non-aging steel has hitherto been developed. The process of this application preferably involves the use of a rimming grade of open hearth steel of the low to medium carbon grades, with sufficient manganese to prevent hot shortness. The invention will be described in connection with such rimming steels, although other grades may be used so long as sufficient manganese is present to prevent hot shortness. Even killed grades of steel may be used following the teachings hereinafter set forth, with certain processing advantages,

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although the greatest benefits of the invention are attained with rimming metal.

The iron or mild steel to which the process of this invention may be applied should have a ladle analysis within substantially the following ranges:

Percent

Carbon ----- .03 to .20

Manganese ----- .01 to 1.0

Sulfur ----- .001 to .10

Silicon ----- 0 to 1.0

Copper ----- 0 to 1.0

Phosphorus ----- 0 to 0.5

Aluminum ----- 0 to .5

Nitrogen ----- .001 to .01

There is a relationship between manganese and sulfur such that, within the ranges set forth above, the lower the sulfur, the lower may be the manganese content. The possibility of a residual aluminum content has been indicated, which would result in a killed or semi-killed steel. Titanium may be used instead of or along with aluminum. The indicated range of nitrogen embraces rimming as well as killed or semi-killed steels. Otherwise than as set forth, the metal will be substantially all iron with such trace impurities as are normal in metal of this general class.

A typical but non-limiting steel within the above ranges may have a ladle analysis as follows:

Percent

Carbon ----- .07

Manganese ----- .34

Sulfur ----- .025

Silicon ----- <.001

Copper ----- .06

Phosphorus ----- .008

Aluminum ----- .005

For a full rimming steel of this analysis, the nitrogen content will be about .0042%. The balance of the composition will be iron as above set forth.

The steel may be produced and refined in the open hearth or by any equivalent process. As indicated, it may be and preferably is a rimming steel. The steel may be cast into ingots, which then are rolled into slabs. The slabs may be reheated and rolled on a continuous hot mill to an intermediate hot rolled gauge. In an alternative procedure the ingots may be rolled directly into slabs or pieces which can be carried down to the intermediate hot rolled gauge without reheating. The steel will be cold rolled to final gauge in one or more stages with such intervening annealing as may be required.

In the manufacture of steel sheet stock for drawing purposes, many routings are possible, including special treatments to contribute special drawing qualities, such as to result, for example, in a certain degree of crystal orientation in the sheet. Also there are treatments which will produce surface conditions especially adapted for drawing. While exemplary routings will be given hereinafter, the attainment of the non-aging quality is accomplished, in accordance with this invention, in a final heat treatment as will hereinafter be described. Consequently, in the broadest aspects of the invention, the nature of the routing up to the final heat treatment does not constitute a necessary limitation. As a generality, the routing will comprise the steps of hot rolling, cold rolling, annealing and, if desired, temper rolling, although the last mentioned step may be omitted in the practice of this invention.

It has been found that when nitrogen is removed from the iron or steel to levels below about .0005 to .0010%, strain aging will be eliminated from the material when it is cooled from a heat treating temperature at rates

normal for box annealing. If the carbon is also removed to very low values, the strain aging can be eliminated even with air cooling. When nitrogen is removed to values less than about .0005%, the yield point of the material will be eliminated when the cooling is slow, i.e. at box annealing rates. The yield point can, however, be eliminated in the low nitrogen material even if it is air cooled, providing the carbon has also been removed to a low value.

In accordance with the teachings of U.S. Patent No. 2,287,467, it is possible to decarburize iron and mild steel sheet stock to low values fairly rapidly and at comparatively low temperatures. Thus, use could be made of a continuous strip annealing practice in an atmosphere of wet hydrogen as described in that patent, if the reduction of carbon were the only consideration. However, it is not possible to remove nitrogen in this way to the low values necessary for the elimination of strain aging and the yield point.

It is possible to remove both the nitrogen and the carbon at suitable temperatures in an atmosphere of wet hydrogen; but since the times required for this are quite long, the operation becomes expensive and adds appreciably to the cost of the steel. A continuous anneal is not available for such an operation. The variables involved are time, gauge, the original carbon content, and the original nitrogen content. The time required will vary approximately with the square of the gauge. Thus, a sheet material .040 in. in thickness will require about four times as long for decarburization and denitriding as a sheet .020 in. in thickness. As distinguished from the decarburization, which is essentially a selective oxidation treatment in a wet decarburizing gas, the elimination of nitrogen to very low levels requires large volumes of hydrogen or other reducing gas which is free from the presence of a nitriding agent such as ammonia. Yet again, the temperatures required for the most efficient removal of carbon are not the same as those required for the most efficient removal of nitrogen.

It is conceivable that entirely different and unrelated practices could be employed for the removal of the carbon and for the removal of the nitrogen. The carbon could be lowered to the desired final level in a continuous anneal while some other kind of treatment could later be employed for the removal of nitrogen. This, in general multiplies equipment costs and processing costs, and is not recommended. At the same time, the principles of this invention are not violated by the practice of a preliminary treatment to remove some portion of the carbon, particularly if the routing contains an intermediate strand or continuous anneal during which some degree of decarburization may be practiced without significantly increasing cost.

In the preferred practice of this invention, both the nitrogen and the carbon are lowered to the desired final levels in a single heat treatment which is not a strand or continuous anneal. Nevertheless, the single heat treatment referred to is divided into various stages as will hereinafter be set forth. By reason of the lengths of time involved, the treatment will be carried on in a box or in a muffle-type furnace wherein control can be exercised both over the temperature and over the atmosphere. It is more difficult to reduce the nitrogen in the steel to the desired low values than it is to reduce the carbon. In the laboratory, where an individual sheet is being handled in a small furnace, it is relatively easy to bathe the surface of the sheet in large volumes of a denitriding gas. This becomes more difficult in plant operations where commercial quantities of the iron or steel are being handled at the same time. In the practice of this invention, where individual sheets are being handled, successful results cannot be obtained by stacking the sheets with or without the commonly used annealing separators. On the contrary, it will be necessary to employ baskets or racks in which the individual sheets can be so positioned

that their surfaces at all times have free access to the annealing atmosphere. In the treatment of iron or steel in coils, the coils must be loosely wound so that the convolutions in them are essentially separated; and it is highly desirable that some means be employed for the forced circulation of the gases between the convolutions. The formation of loose coils can be accomplished either by winding a strand with the strip in the formation of the coils, and subsequently removing the strand before annealing, or by winding into the coil between the convolutions thereof a metallic means which will both separate the convolutions and provide for the passage of the annealing atmosphere between them because the metallic means, generally in the form of a strand, is so constructed as to contact the convolutions at intervals only, leaving elsewhere a space for the passage of the annealing atmosphere between a convolution and the separating strand.

The annealing procedure, as above indicated, will be divided into parts. There will be a part in which the temperature of the material being treated will be brought up to a desired temperature level. There will be a part in which the material is soaked at the aforementioned temperature level. Since the temperature for decarburization is normally less than the temperature desired for denitriding, there will preferably be a second soaking period separated from the first by a length of time necessary to permit the attainment of the higher temperature. Finally, there will be a part in which the material is cooled from the high temperature to a temperature suitable for discharge of the material from the box or muffle into the open air.

Atmospheric changes are preferably caused to take place during the annealing treatment, so that different atmospheres will be present during the various parts thereof. Thus in accordance with the present invention, a particular atmosphere may be employed during the initial heating up part of the heat treatment. In many instances the same atmosphere may be used during the cooling part. It is essential that this atmosphere be effective for the removal of carbon; but it is not necessary that the atmosphere be wet hydrogen, as hereinafter defined. It may be and preferably is a less expensive type of atmosphere.

As the less expensive atmosphere, various decarburizing gases may be used, and in particular gases containing relatively small amounts of decarburizing gases such as carbon dioxide and water vapor, together with a preponderant amount of diluent gas such as nitrogen. Of course, if water vapor is present, hydrogen should also be present to prevent oxidation of the iron. The skilled worker in the art will recognize that there are numerous gases of this character. For example, DX gas, which is formed by the incomplete combustion of natural gas, may vary as to composition, but when formed by burning natural gas with air in a ratio of 1:6, will contain about 7% CO₂, 8% CO, 11.8% H₂, the balance being substantially all nitrogen. This gas may be used with a dew point of about 60° to 80° F., and will be found to be effective in decarburization since it will oxidize carbon but will not significantly oxidize iron at temperatures above 1100° F. It may be noted that if the dew point of the DX (1:6) gas goes too far below 30° F., the gas may become carburizing in nature.

A leaner DX ratio will require a lower dew point than a gas of stronger reducing potential, to prevent scaling, in accordance with an equilibrium which may be expressed as the partial pressure of hydrogen divided by the partial pressure of water. An equilibrium of this character exists also for dissociated ammonia, HNX gas and even for pure hydrogen.

HNX gas is one containing generally from about 6% to 10% hydrogen, the balance being nitrogen. It is available in a number of plants at a relatively low cost. Its origin may be a lean DX gas with the carbon dioxide and carbon monoxide removed, or it may be formed as such

by mixing hydrogen with nitrogen (usually obtained as an oxygen plant byproduct). The HNX gas should be free of oxygen. It will serve as a wet decarburizing medium for purposes of this invention when used with a dew point of about 60° F.

Cracked or dissociated ammonia may also be used in wet condition as a decarburizing medium. It contains generally about 75% hydrogen and 25% nitrogen. As ordinarily produced, it is substantially free of ammonia, the ammonia content being from 0 to about .05%. Means are available to remove free ammonia to less than about one part per billion. The dissociated ammonia may be used with a dew point as high as 140° F.; but this gas, as compared with DX gas or HNX gas is relatively expensive so that it is not preferred for economic reasons.

In the practice of the invention the iron or steel to be treated is placed, as described above, in a box or muffle, and the application of heat is started. The so-called less expensive atmosphere may be introduced into the furnace before or after the application of heat is begun. The less expensive gas serves several functions. At the lower temperatures of the heating-up part of the annealing treatment, it protects the iron or steel from undue oxidation. When the temperature of the stock reaches about 1100° F., effective decarburization begins. The rate of decarburization increases with temperature, being relatively slow when the temperature is about 1100° F. but proceeding quite rapidly as the temperature rises into the range of about 1200° to 1400° F. As has already been indicated, the time required for decarburization will depend on several factors, such as temperature, gauge, initial carbon content and the like. Nevertheless, decarburization is an equilibrium phenomenon, and some gaseous atmospheres will remove carbon to a greater extent than will others, all attending conditions remaining the same. Within the range of about 1200° to 1400° F., a DX gas as described will generally reduce the carbon content of the stock to about .005% or less. Wet dissociated ammonia under similar conditions will still further reduce the carbon, usually to the order of about .001%. A more rapid removal of carbon could be attained at higher temperatures in the same atmospheres, for example, at a temperature of 1500° F.; but at such temperatures, there is likely to be an undesirable grain growth in the iron or steel material which will impair its drawing qualities. It may be noted also that a circulation within the box or muffle of the so-called less expensive atmospheres set forth above will act to sweep out of the annealing chamber vaporized or cracked oils or greases which may be resident on the strip as it comes from the mill.

The presence of nitrogen in considerable quantities in the so-called less expensive atmospheres of this invention does not tend to nitride the stock. On the other hand, the denitrifying phenomenon is dependent to a considerable degree upon the partial pressure of nitrogen in the furnace atmosphere. Consequently, atmospheres containing appreciable quantities of nitrogen, such as the atmospheres mentioned above, are not suitable for the denitrifying step. Some nitrogen may be removed; but the nitrogen content becomes stabilized at a value too high to be effective for the elimination of strain aging and yield point. For example, it has not been found possible to reduce the nitrogen in the iron or steel to a value below about .002% in an atmosphere of DX gas.

The elimination of nitrogen, for the same reasons, requires a reasonably rapid flow of the denitrifying gas past the surfaces of the stock. Nitrogen eliminated from the stock forms ammonia with the hydrogen of the denitrifying gas; but even small quantities of ammonia in gas remaining in contact with the metal surfaces will serve to poison the furnace atmosphere. It is not possible to give a specific rate of flow of the denitrifying atmosphere since the characteristics of boxes and muffle furnaces will vary as to the actual movement of gases across all surfaces

of the metal being treated irrespective of the total input and withdrawal of the denitrifying gas. Even with the maximum circulation, such as may be obtained in a laboratory furnace in which a single sheet is being treated, the so-called less expensive atmospheres are not suitable for denitrifying. Cracked or dissociated ammonia, by reason of its relatively large hydrogen content, is more effective than DX gas or HNX gas. But in a series of tests, it was shown that 15 hours at 1200° F. in wet dissociated ammonia was required to reduce the nitrogen content of a particular steel to .0005%, and 9 hours at 1300° F.

As a consequence of these considerations, the denitrifying atmosphere preferred is an atmosphere of wet hydrogen, not containing any significant amount of nitrogen. The hydrogen may, if desired, be diluted with some inert gas other than nitrogen, although this may not necessarily lead to economy.

When a sufficient decarburization has occurred, the atmosphere in the box or muffle is changed to a suitable denitrifying atmosphere having a dew point of about 100° F. It is not necessary to effect a thorough-going decarburization in the early stages of the procedure; but it is economically advantageous so to do. The wet hydrogen, which is the preferred denitrifying atmosphere is also an efficient decarburizer; but reliance upon pure wet hydrogen for both decarburization and denitrifying is more costly than is a process in which the metal is heated up in one of the so-called less expensive atmospheres to a temperature suitable for decarburization and then is soaked at that temperature before the introduction of the pure wet hydrogen. Nevertheless, in certain tests pure hydrogen having a dew point of about 100° F. was found effective both in reducing carbon to below .0015% and in reducing nitrogen to below .0005% in 5 hours at temperatures between 1200° F. and 1300° F. The same effect was obtained with a soaking period of 3 hours at 1400° F. when the hydrogen had a dew point of 120° F.

The desired temperature for denitrifying may be the same as, or higher or lower than, the optimum temperature for decarburization in the less expensive gas. Changing the atmosphere in the box or muffle of necessity is a process of dilution so that the change does not occur instantaneously. However, it can easily be accomplished during the time required to change from one soaking temperature to another. The soaking temperature for denitrifying will vary with the circumstances outlined above, e.g. gauge, initial nitrogen content, and time of treatment. It should be noted that in any of the procedures, of which certain examples are given hereinafter, decarburization and denitrifying will be going on at the same time. However, it is possible to test for the extent of decarburization by analyzing gases withdrawn from the box or muffle and noting the point at which carbon bearing gases level off at a minimum value. It is also possible to test for the completion of the denitrifying reaction by analyzing the effluent gases for ammonia. Where there has been a soaking heat treatment in a circulating atmosphere of wet pure hydrogen or wet hydrogen containing inert gases other than nitrogen, the reduction of nitrogen in the iron or steel to a value at least as low as .0005% will be indicated by the absence of ammonia in the effluent gas.

When the process has otherwise been completed, i.e. when both the carbon and the nitrogen have been reduced to the extent necessary, the heat may be turned off or diminished, and one of the less expensive gases above set forth may then be introduced into the box or muffle to replace the denitrifying atmosphere. Reducing the temperature of the stock to the neighborhood of 1000° F. before changing atmospheres insures against a reversion of the nitrogen content. At the same time it obviates the use of the more expensive denitrifying gas during the greater length of time occupied by the cooling part of the process. Circulation should, of course, be maintained; and the term "circulation" as used herein is intended to

embrace not only the continuous introduction and withdrawal of gases as respects the box or muffle, but also such movement of gases within the box or muffle to cause all parts of the iron or steel surfaces to be bathed in changing volumes of the gases.

Whether the decarburization is done by the nitrogen bearing less expensive gases, or by the wet hydrogen or other denitrifying atmosphere, or both, it has been found that, in the practice of this process, where there is a substantial soaking period in a circulating atmosphere of denitrifying gas, a continuation of the heat treatment until the denitrifying gas is shown to be free of ammonia will insure a reduction of the nitrogen content of the stock to a value not greater than about .0005% and an adequate decarburization. Putting this another way, if in the process hereinabove described the stock is denitrified to a value of .0005%, the carbon content of the stock will be found to have been reduced to a value no higher than about .002%.

Certain illustrative and exemplary procedures will now be outlined in brief form.

Example I

(1) Hot reduce the metal to an intermediate gauge.
(2) Cold reduce the intermediate gauge metal to the desired final gauge. The intermediate and final gauges as such do not constitute a limitation on the invention, as will be understood; but since the gauge of the material is one of the factors affecting the soaking period hereinafter set forth, the final gauge material in this and the following two examples may be considered as having a thickness of .020 in.

(3) Heat the stock to 1200° F. in a DX gas (1:6 ratio) having an 80° F. dew point.

(4) When the stock has reached about 1200° F., discontinue the introduction of the DX gas and introduce hydrogen having a 120° F. dew point, while raising the temperature of the stock to about 1300° F.

(5) Soak at 1300° F. with continuous circulation of the wet hydrogen until the effluent gas shows no trace of ammonia. Denitrifying should now be complete.

(6) Cool the stock to about 1100° F. without opening the box or muffle.

(7) Introduce DX gas of the same ratio as above indicated and at a dew point of between about 40° and about 80° F.

(8) Cool the stock while in the circulating DX gas atmosphere to a temperature of about 300° F. before uncovering.

With stock about .020 in. in thickness, the soaking time in the above example will generally be about 3 to 5 hours.

Example II

(1) Hot reduce as before.

(2) Cold reduce with about a 75% reduction.

(3) Heat the stock to a temperature of about 1450° F. in DX gas (1:6 ratio) having an 80° F. dew point.

(4) Soak for about 2 hours at the indicated temperature.

(5) Introduce hydrogen having a 130° F. dew point while cooling the stock in the box or muffle to about 1300° F.

(6) Soak the stock at about 1300° F. until the effluent gas shows no trace of ammonia.

(7) Cool to about 1000° F.

(8) Introduce DX gas having the indicated ratio and a 40° F. dew point.

(9) Cool to 300° F. in the DX gas before uncovering.

Example III

(1) Hot reduce to final gauge.

(2) Heat the stock to about 1350° F. in DX gas (1:6 ratio) at 75° F. dew point.

(3) Soak until the carbon bearing gases in the effluent gas from the box or muffle drop to a minimum indicat-

ing that decarburization has reached an equilibrium point.

(4) Introduce hydrogen at 115° F. dew point.

(5) Soak at the indicated temperature with circulation of the wet hydrogen until ammonia is shown to be absent in the effluent gas.

(6) Start cooling and at the same time start introducing DX gas into the box or muffle.

(7) Cool the stock to 300° F. in the DX gas atmosphere before opening the box or muffle.

In the above examples various steps may be modified or interchanged.

In the actual practice of the above examples, using material of the exemplary formula, a material having a yield strength of 12,000 to 17,000 p.s.i., a tensile strength of 35,000 to 45,000 p.s.i., an elongation of 35% to 55% and a Rockwell B hardness of 20 to 40 has been produced.

Other routings may be employed if desired such as routings set forth in the copending application of Robert H. Heyer, Serial No. 27,516, filed May 9, 1960, entitled Oriented Cold Rolled Drawing Steel, and assigned to the same assignee. The uses to which products of the present invention are to be put do not constitute limitations herein.

Modifications may be made in the invention without departing from the spirit thereof. The invention having been described in certain exemplary embodiments, what is claimed as new and desired to be secured by Letters Patent is:

1. A process of producing non-aging mild steel sheet stock for drawing purposes, said stock initially containing at least about .03% carbon and at least about .004% nitrogen, which comprises reducing said ferrous material to gauge, heat treating it in a decarburizing atmosphere having a dew point of at least about 60° F. and consisting essentially of nitrogen in preponderant quantity, sufficient hydrogen to prevent oxidation of the iron in said ferrous material, and minor quantities of carbon dioxide and carbon monoxide, whereby to reduce its carbon content to a value not greater than about .005%, and thereafter heat treating it in a furnace having an atmosphere preponderantly of hydrogen with a dew point of at least about 100° F., said atmosphere having a partial pressure of nitrogen sufficiently low to permit the reduction of nitrogen in the ferrous material to the range of about .001% to about .0005% and lower, while also reducing the carbon content to a value not greater than about .002%, and continuing the last mentioned heat treatment while passing the said atmosphere continuously over the surfaces of the ferrous material and out of the furnace, until the effluent atmosphere ceases to show traces of ammonia.

2. The process claimed in claim 1 in which both heat treatments are carried on in a range of at least about 1100° F. up to about 1500° F.

3. The process claimed in claim 2 in which, after the effluent atmosphere in the second mentioned heat treatment ceases to show traces of ammonia, the said wet atmosphere preponderantly of hydrogen is changed to a non-oxidizing atmosphere preponderantly of gases other than hydrogen during the cooling of the ferrous material.

4. The process claimed in claim 3 wherein the first mentioned atmosphere is a wet atmosphere chosen from a class consisting of DX gas, HNX gas, and mixtures thereof.

5. The process claimed in claim 4 wherein said first mentioned atmosphere is an atmosphere of DX gas having a dew point of about 60° to 80° F.

6. The process claimed in claim 4 wherein the first heat treatment is carried on at a temperature of substantially 1100 to 1400° F., in a furnace, and the said atmosphere is passed continuously over the surfaces of the ferrous material and out of the said furnace, the said heat treatment being carried on until the effluent

atmosphere attains substantial equilibrium as to its carbon content.

7. The process claimed in claim 5 wherein the second mentioned atmosphere is a wet atmosphere chosen from a class consisting of hydrogen, dissociated ammonia, and mixtures thereof.

8. The process claimed in claim 7 wherein the said heat treatments and the cooling are carried on in a single furnace wherein the material is in the form of an open coil, and wherein means are provided to cause the circulation of the atmosphere between the convolutions of the coil.

9. The process claimed in claim 8 wherein the ferrous material contains initially from about .03 to about .20% carbon, from about .01 to about 1.0% manganese, from about .001 to about .10% sulphur, from about .001 to about .01% nitrogen, minor quantities, if any, of silicon, copper, phosphorus, and aluminum, the balance being substantially all iron.

10. The process claimed in claim 9 wherein the ferrous material is a rimming steel.

11. A process of producing non-aging iron and mild steel sheet stock for drawing purposes containing at least about .03% carbon and at least about .004% nitrogen which comprises reducing the said ferrous material to gauge, placing it in the form of an open coil within a muffle furnace having means for the circulation of furnace atmosphere over the surfaces of the coil convolutions, and heating the stock to about 1200° F. in a DX gas having about an 80 degree dew point, and, when the ferrous material has reached a temperature of about 1200° F., discontinuing the introduction of the DX gas into the furnace, and introducing hydrogen therein, the hydrogen having a dew point of about 120° F., while raising the temperature of the ferrous material to about 1300° F., soaking the ferrous material at the last mentioned temperature with continuous circulation of the wet hydrogen until the effluent gas from the furnace shows no trace of ammonia, cooling the stock to about 1100° F. in the said furnace, then introducing DX gas into the furnace at a dew point of between about 40° and 80° F., while permitting the ferrous material in the last mentioned gas to cool to a temperature of about 300° F.

12. A process of producing non-aging sheet stock for drawing purposes from a rimming steel, containing at least about .03% carbon and at least about .004% nitrogen which comprises reducing the steel to gauge by cold rolling following hot rolling, placing the steel in the form of a coil with open convolutions in a muffle

furnace having means for the entrance and exit of annealing atmosphere, as well as means for the circulation of the atmosphere within the furnace over the surfaces of the convolutions of the coil, heating the steel in the said furnace to a temperature of about 1450° F. in a DX gas having about an 80° F. dew point, soaking the steel in the said atmosphere for about two hours at about 1450° F., then introducing hydrogen having a 130° F. dew point while cooling the steel in the furnace to about 1300° F., soaking the steel at about 1300° F. in hydrogen until the effluent gas shows no trace of ammonia, cooling the said steel to about 1000° F., then introducing DX gas having about a 40° F. dew point, and cooling the steel in the furnace to about 300° F.

13. A process of producing non-aging iron and mild steel sheet stock for drawing purposes containing at least about .03% carbon and at least about .004% nitrogen which comprises reducing the said ferrous material to a final gauge, placing the ferrous material in the form of a coil with loose convolutions in a muffle type furnace having means for the entrance, exit and circulation of annealing atmospheres, heating the ferrous material in the said furnace to about 1350° F. in a DX gas having a dew point of about 75° F., until the carbon bearing gases in the effluent from the furnace drop to a minimum indicating that decarburization has reached an equilibrium point, introducing hydrogen at a dew point of about 115° F., soaking the ferrous material at about said temperature of 1350° F. in the said hydrogen atmosphere with circulation thereof, until ammonia is shown to be absent in the effluent gas, permitting the ferrous material to cool within the said furnace while introducing DX gas into the furnace beginning at about the time of the start of the cooling, and cooling the said ferrous material in the said DX gas to a temperature of about 300° F.

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DAVID L. RECK, *Primary Examiner.*