Oct. 30, 1956 E. J. SEABOLD ET AL 2,768,916

CONTINUOUS BLUING SYSTEM FOR FERROUS STRIP

Filed Nov. 13, 1951 3 Sheets-Sheet 1

Fig. 1.

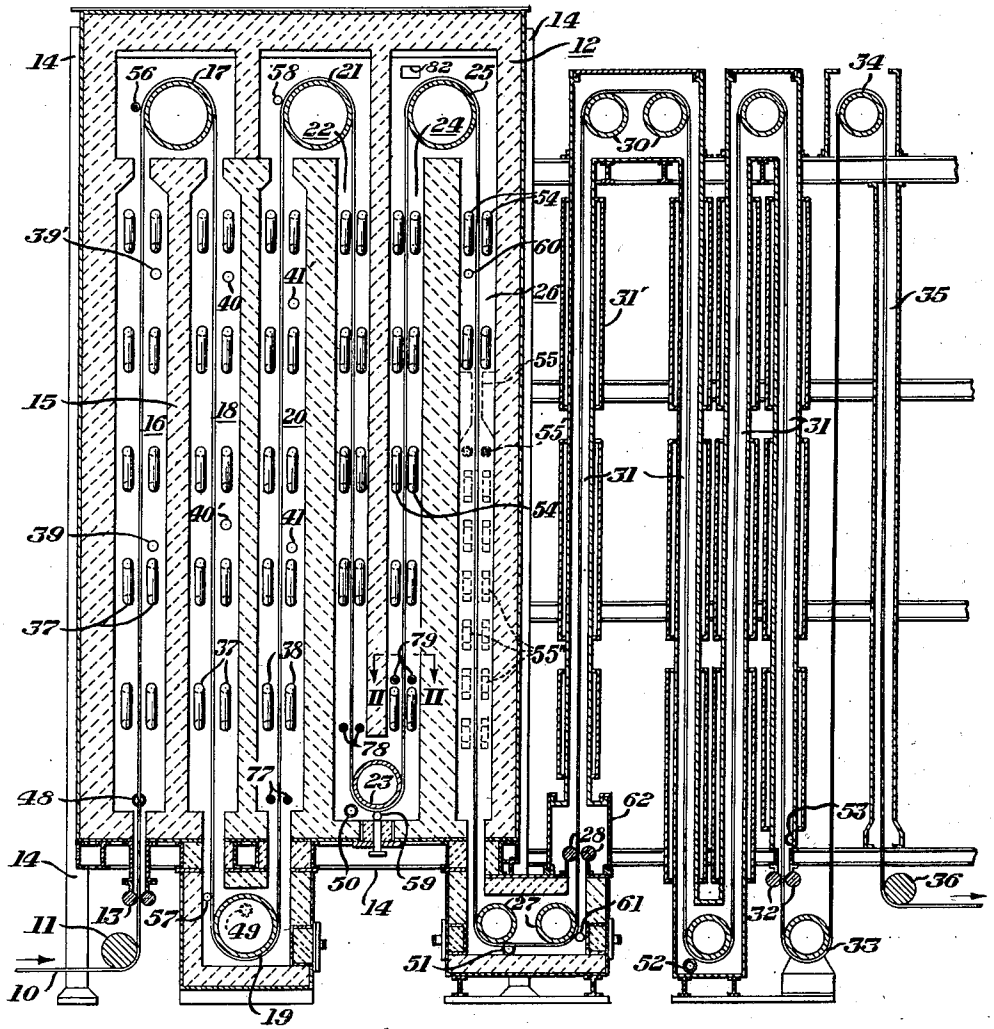
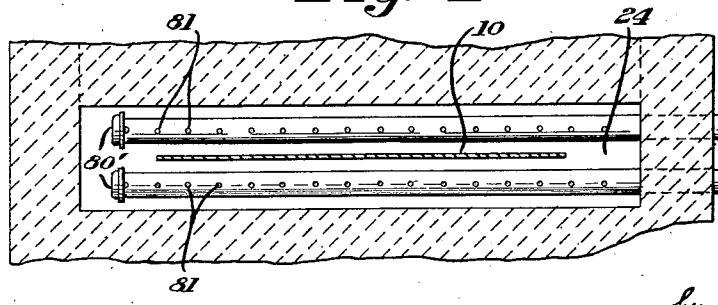



Fig. 2.




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CONTINUOUS BLUING SYSTEM FOR FERROUS STRIP

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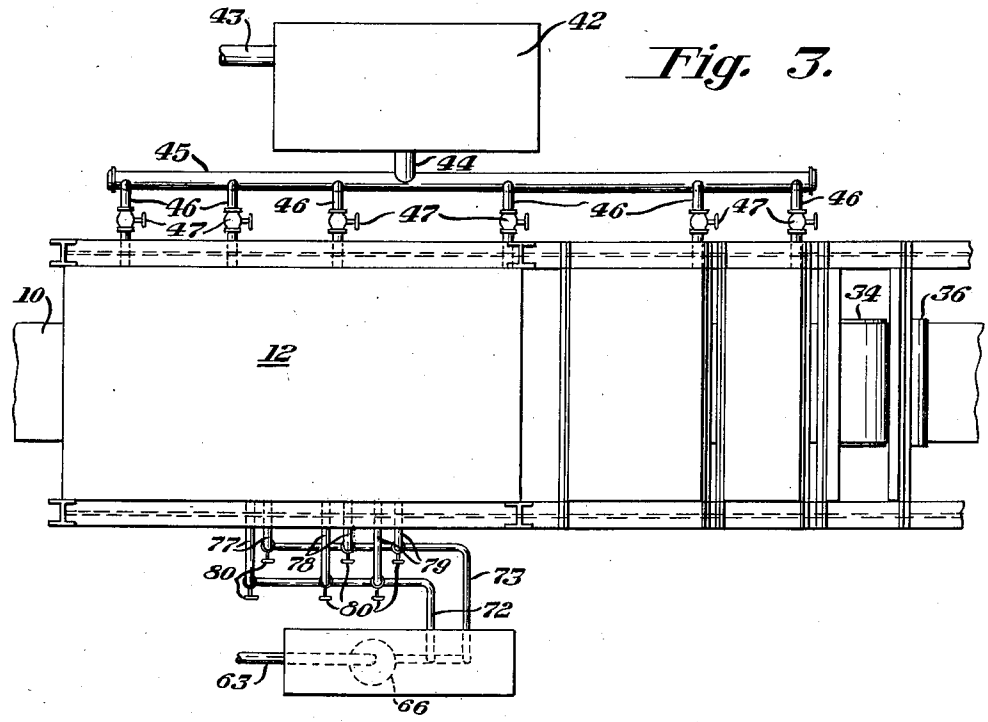



Fig. 3.

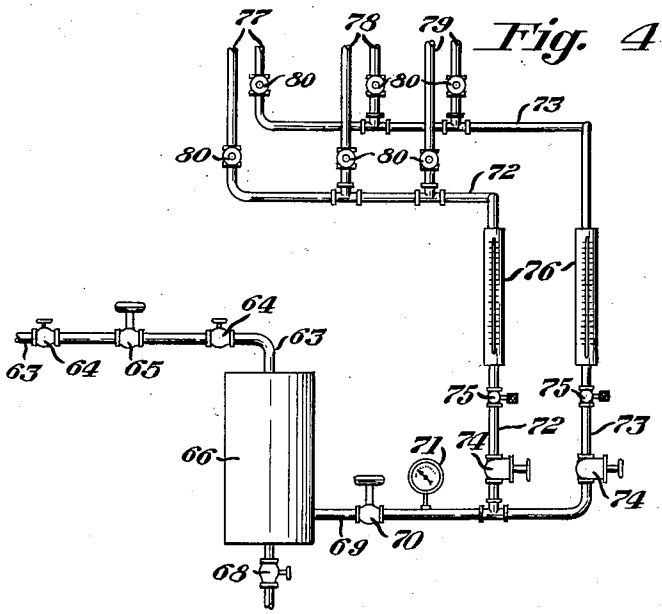



Fig. 4.

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Oct. 30, 1956 E. J. SEABOLD ET AL 2,768,916

CONTINUOUS BLUING SYSTEM FOR FERROUS STRIP

Filed Nov. 13, 1951 3 Sheets-Sheet 3

Fig. 6.

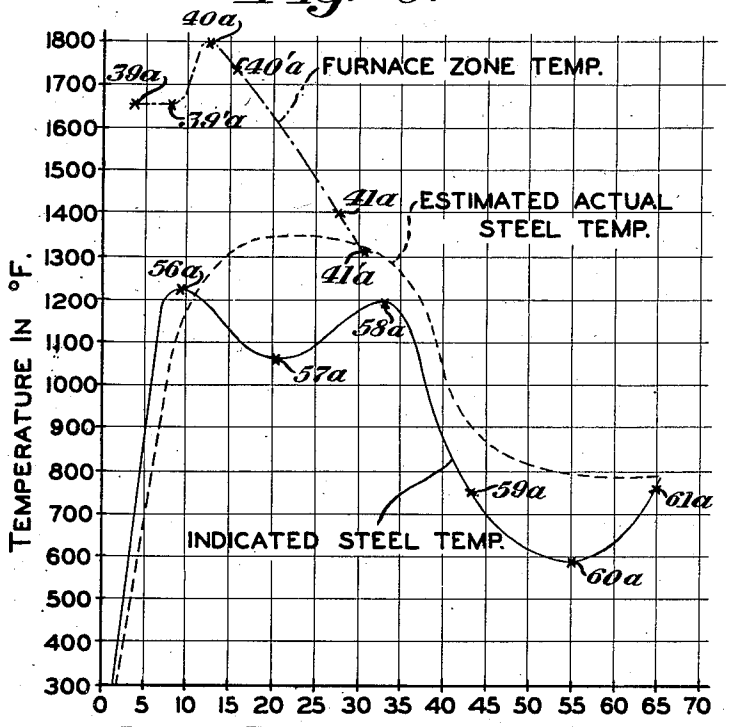
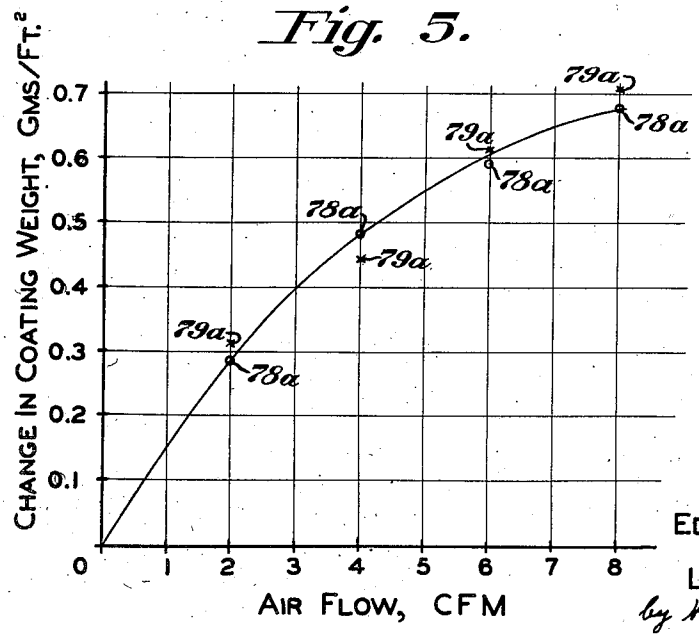



Fig. 5.




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United States Patent Office 2,768,916 Patented Oct. 30, 1956



2,768,916

# CONTINUOUS BLUING SYSTEM FOR FERROUS STRIP

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Application November 13, 1951, Serial No. 255,978

12 Claims. (Cl. 148—6.35)

The invention relates to method and apparatus for the continuous bluing of ferrous strip in the course of the continuous annealing thereof in strand form. More particularly, the new system of this invention comprehends flexibly controlled production of blued ferrous strip, having uniform and desirable qualities, at relatively high speeds with the use of measured introduction of oxygen-containing gas.

Heretofore, blued plate has been produced from ferrous strip in a variety of ways. In one operation, the metal was heated in a strip furnace to a temperature about 1350° F. while maintaining a reducing atmosphere within that furnace. After cooling to a temperature between about 900° F. and 1200° F., the strip was discharged from the furnace into the open air to blue it. The blued product was useful for some purposes but might lack uniformity in one or more of the qualities of color, weight, or adherence between the metal of the strip and the oxide coating. Frequently, the two sides of the same strip so treated also varied. In addition to any variation, there was no practicable control of the production of such a blued product to obtain predetermined characteristics in the respective blue coating. In general, the air blued product was inferior in many respects to the blued product produced by conventional steam bluing under cover.

While the color of the product produced by steam bluing has usually been considered more attractive, there are a number of disadvantages to that type of operation. Thus, there is the additional handling and work required to loosen the coils before putting them under the cover of, for example, an annealing box type of furnace. Even with such loosening, the color and weight of the bluing along and across the width of the strip were frequently uneven, producing the so-called "light center" in many cases which might require rebluing. Moreover, the adherency of the oxide coating produced by the steam bluing was not always uniform and in some cases a part of the coating might be readily rubbed off. As in the case of the air bluing, there was no practicable control for purposes of producing uniformity of product bluing or of maintaining that uniformity for any variation in the specification as to coating qualities or annealing treatment.

In the new system of this invention, a practicable control for a bluing operation is provided which is sufficiently flexible to meet any particular specification among a variety. Further, in that new system, the blued product so produced is uniform and reproducible at will. Moreover, in the new system the bluing is performed in the course of a readily controllable strand annealing operation at relatively high speeds while eliminating extra handling and heating and reruns of rejected material. In addition, the blued product of this new system compares favorably in color, weight and adherency with the best output of older kinds of bluing operations on ferrous strip and is superior to the product produced by the older practices. The new system is flexible in control and economical in operation in a manner not heretofore obtainable.

Other objects and advantages of this invention will be apparent from the following description and from the



following drawings, which are illustrative only, in which

Figure 1 is a vertical section through a portion of a strip furnace which has been modified to practice one embodiment of the new system of this invention;

Figure 2 is a detail of the apparatus shown in Figure 1 taken along line II—II of Figure 1;

Figure 3 is a plan view of the structure shown in Figure 1 with the addition thereto of a unit capable of supplying the furnace with a controlled furnace gas atmosphere and with the further addition of a unit for introducing a measured amount of an oxygen-containing gas such as air in accordance with one practice of the new system of this invention;

Figure 4 is an enlarged view in elevation of the unit shown in Figure 3;

Figure 5 is a diagram plotting change in weight of the oxide coating against the volume of air introduced in accordance with one practice of the new system of this invention; and

Figure 6 is a diagram in which temperature is plotted against time in illustrating an operation in accordance with the new system of this invention.

Referring to the drawings, a ferrous strip 10 passes around a guide roll 11 and enters a tower type of furnace 12 through a pair of entry roll seals 13. Furnace 12 is suitably constructed of refractory material duly supported on structural metal frame members 14. A series of parallel internal walls 15 of refractory material define a number of parallel vertical pass chambers through which strip 10 is threaded. Thus, as strip 10 enters furnace 12 it moves through a first pass 16, around a furnace roll 17, through a second pass 18, around a furnace roll 19, through a third pass 20, around a furnace roll 21, through a fourth pass 22, around a furnace roll 23, through a fifth pass 24, around a furnace roll 25, and through a sixth and final pass 26 in furnace 12 proper. Strip 10 then passes around guide rolls 27 and exits from furnace 12 through the exit roll seals 28. Water-cooling chutes 31 with appropriate rolls 30 and cooling jackets 31' may be provided in tower arrangement as illustrated for the further cooling of strip 10 under controlled conditions and at a predetermined rate. Following the water-cooling chutes, strip 10 in its continuous movement passes through discharge roll seals 32. Strip 10 may then pass into the open air between rolls 33 and 34 where it may be inspected visually on either or both sides thereof. Then strip 10 enters air-cooling chute 35 before passing around a guide roller 36 toward a conventional pair of pinch rolls (not illustrated) which at least assist in continuously pulling strip 10 through furnace 12 and the respective chutes before passing it onto a coiler on which strip 10 is reeled. Similarly, an uncoiling reel and pinch rolls may be provided at the entry end of the pass line of strip 10 in advance of furnace 12. Generally, the strip 10 will also be threaded around an entry looper and an exit looper respectively in advance of and following the structure shown in Figure 1 for a purpose that is well known in the operation of a tower type strand treatment furnace.

Conventional radiant heating tubes 37 and 38, or electric resistance heaters, may be provided on both sides of strip 10 in the pass chambers 16, 18 and 20. Thus, the first and second passes 16 and 18 respectively may be employed to raise strip 10 to annealing temperature while subjecting it to such heat treatment for such time as it takes strip 10 to move through passes 16 and 18. Pass chamber 20 may be employed as a heating or a soaking chamber. In soaking, the radiant tubes 38 therein would generally be heated to a degree, for example, sufficient only to maintain the temperature of strip 10 substantially constant while passing through chamber 20, which

temperature and time of passage would correspond to that required for the achievement of the metallurgical properties sought. Indeed, the character of strand furnace used, the number of furnace passes and chutes, and, the temperature conditions and rates provided may be varied widely without departing from their ability to partake in a practice of the new system of this invention.

Control of the heating in the pass chambers 16, 18 and 20, respectively, may be obtained by means of zone thermocouples connected to suitable equipment to maintain the furnace gas atmosphere in the respective chambers at the desired temperature. For example, the zone thermocouples 39 and 39' may be used to control the temperature in pass chamber 16; zone couples 40 and 40' may be used to control the zone temperature in pass chamber 18, the settings of such thermocouples being respectively independent to provide control of the gas firing of the radiant tubes 37 adjacent the respective thermocouples by means which will be well understood. The temperature of the tubes in turn regulate the temperature of the adjacent interior space zone of furnace 12. Similarly, zone thermocouples 41 and 41' may be of suitable nature to control the gas firing of radiant tubes 38 and thereby the temperature of the pass 20.

The furnace gas atmosphere for the interior spaces of the apparatus shown in Figure 1 may be provided by means of a supply from a battery of "bottled" gas of appropriate composition or by means of a furnace gas atmosphere generator machine. Thus, conventional "Kemp" machine 42 may be used to partially burn gaseous fuel such as natural gas, for example, entering machine 42 through a pipe 43, the extent of such burning determining the initial composition at least of the gaseous effluent from machine 42 which passes generally at a slight positive gauge pressure through an outlet pipe 44 into a manifold 45 and branches 46 to provide the gas atmosphere within furnace 12, and, if desired, within the chutes 31. A valve 47 in each branch 46 permits the throttling of the particular branch or the full opening or full closure of each respective branch 46 to provide introduction of such controlled composition atmosphere into the apparatus for the practice of the new system of this invention at the desired points for general uniformity. Thus, the respective branches 46 from left to right as viewed in Figure 3 may be in communication with the interior spaces of furnace 12 and chutes 31, as shown in Figure 1, through the openings respectively numbered 48 to 53, inclusive. In general, openings 48 and 49 are left open or at least are never fully closed. Before operations begin, the interior spaces of the apparatus shown in Figure 1 are generally purged with an inert gas such as nitrogen to insure uniform operation and prevent the presence or build-up of any explosive gaseous mixtures within such interior spaces.

Pass chambers 22, 24 and 26 may be used for initial controlled cooling in the embodiment shown, such cooling being obtained, for example, by the circulation of water through the cooling tubes 54 positioned therein on both sides of the strip 10. In some cases, a final pass chamber such as chamber 26 may have a baffle 55 positioned therein as shown in dotted outline in which event the cooling tubes 54 will terminate in that pass chamber on the approach side of the refractory baffle 55. In such case, the portion of pass chamber 26 below baffle 55 may be used as a reheating section, using conventional radiant tubes or electric resistance heaters 55 therein on each side of the strip between baffle 55 and the exit end of the pass chamber. Where such a reheating section is employed, the temperature to which the strip is raised therein should not exceed about 1050° F. and generally will be lower than but above about 750° F. in a practice of this invention.

In controlling the temperature of the metal of strip 10 in the practice of the new system, the aid of the readings of a number of suitable thermocouples respectively numbered 56 to 61, inclusive, and located as shown in Figure 1 may be employed, although other locations, as will be understood by those skilled in the art, may be used within the interior spaces of furnace 12. In general, thermocouples 56 to 61, inclusive, will be positioned as close to the surface of the strip 10 passing through furnace 12 as is practicable to minimize error in the respective indications of such thermocouples. Such readings or indications are guides for use in adjusting the settings of the zone thermocouples 39 to 41', inclusive, to produce the particular metal temperature and rate of change of temperature in the strip 10 selected for the particular and respective passes in furnace 12. The steel temperature thermocouples 56 to 61 may be provided with indicating, recording or automatic controlling devices responsive respectively to them for use in controlling the operation in whatever manner is selected. Similar indicating, recording or controlling devices may also be employed in conjunction with the chutes 31 to provide control of the particular cooling rate therein prescribed for the particular composition and treatment of metal strip 10.



The apparatus shown in Figure 1 is substantially gastight and the interior spaces thereof between the entry roll seals 13 and the exit roll seals 28 are usually maintained at a positive gauge pressure, usually just above the ambient atmospheric pressure of the open air, to insure against inward leakage of the air surrounding the outside of the apparatus. Bell cover 62 is normally closed in an operation in accordance with this invention and with cover 62 closed, the chutes 31 are also subtsantially gastight between the exit roll seals 28 and the discharge roll seals 32. The furnace gas entering the interior spaces of the apparatus shown in Figure 1 through one or more of the openings 48 to 53, inclusive, is generally at no higher temperature than that occasioned by the partial combustion in machine 42 and it may be at room temperature. In general, a single atmosphere will be supplied in common to all of the interior spaces of the apparatus shown in Figure 1 and will be of a character which is non-sealing (that is, substantially non-oxidizing) and also non-reducing insofar as the coating is concerned which is produced by the new system of this invention. The gaseous fuel supplied to machine 42 through pipe 43 is usually supplied at ambient temperature.

In bluing ferrous strip 10 in accordance with one practice of this invention, an oxygen-containing gas such as air may be compressed in a suitable compressor, the outlet of which is connected to a pipe 63 having valves 64 connected therein on each side of an automatic adjustable pressure regulator valve 65. A pressure receiving tank 66 is connected to the discharge end of pipe 63 and is provided with a drain 67 having a normally closed valve 68 connected therein. An outlet pipe 69 is provided in communication with the interior of tank 66 and has connected therein an adjustable pressure regulator valve 70 for further reducing the pressure of an oxygen-containing gas entering pipe 63. A conventional pressure gauge 71 may also be connected to pipe 69 on the discharge side of valve 70 to indicate the pressure at which the oxygen-containing gas such as air is introduced into the interior spaces of furnace 12. Pipe 69 is provided with the respective branch pipes 72 and 73 each of which has a gate valve 74 and a needle valve 75 connected therein in series. On the delivery side of each needle valve 75 there is an indicating flowmeter 76 from which the respective branches 72 and 73 continue to supply the left and right sides respectively as viewed in Figure 4 of three pairs of admission pipes, the pairs being respectively numbered 77, 78 and 79. A valve 80 is connected between each admission pipe and its supplying branch pipe so that each admission pipe can be regulated individually relative to the other admission pipe in the same pair and relative to admission pipes in other pairs. Normally, only one of the respective pairs 77 to 79, inclusive, of admission pipes will be open at one time.

A suitable construction for each pair of admission pipes is generally indicated in the detailed view of Figure 2 showing the admission pipes **79**. Each such admission pipe is provided with a cap **80'** and is perforated through its walls by means of a series of parallel drilled openings **81** forming nozzles for the discharge of the oxygen-containing gas entering the respective branches **72** and **73**. As shown, the openings **81** are preferably positioned to direct the exiting gas parallel to strip **10** and thereby avoid direct impingement upon the strip **10**. In general also, the tubes **38** and **54** in the particular pass in which the respective pairs of admission pipes are located are spaced as to provide a clearance relative to the openings **81** in each of the pairs **77** to **79**, inclusive. Thus, it will be noted that in pass chamber **24** the tubes **54** are spaced from openings **81** in admission pipes **79** to permit access of the oxygen-containing gas issuing from pipes **79** to readily flow into contact with the surface of strip **10** passing that point at the time being. Similar clearance provision is made in the cases of the pairs of admission pipes **77** and **78**. Preferably, any admission of furnace atmosphere gas through inlet pipe **50** is avoided whenever air or other oxygen-containing gas is admitted through pair **78** or pair **79** of the admission pipes to minimize any dilution of the gas issuing from such admission pipes. On the other hand, such gas issuing from such admission pipes appears to have a preferential affinity relative to the oxidation of the surface of a strip **10** passing through the zone of the admission pipes in question.

In one operation of the new system of this invention, a strip **10** of ferrous metal may enter the entry roll seals **13** at ambient temperature which may be about 70° F. and be raised to a temperature in the neighborhood of between from about 1000° F. to about 1450° F. in pass chamber **16**. In passing through the pass chamber **18**, although the furnace gas atmosphere in that zone may reach a higher temperature by virtue of the setting of thermocouples **40**, for example, the temperature of the steel is generally caused to continue to rise before passing into pass chamber **20** where it may be subjected to soaking by generally holding its temperature relatively constant and in the neighborhood of, for example, between from about 1250° F. to about 1400° F. In passing through the fourth pass chamber **22**, the temperature of the steel strip may be dropped at a controllable rate to a temperature in the neighborhood of between about 1000° F. and 800° F. at the lower end of chamber **22**. Further cooling may take place in the fifth pass chamber **24** with the temperature of the steel being lowered further to a temperature in the neighborhood of between from about 750° F. and about 900° F.



The actual steel temperatures may be somewhat different than the respective indicated thermocouple temperatures of thermocouples 56 to 61, inclusive, substantially in passes **16** to **24**, respectively. As will be well understood, the correction to be applied to a particular thermocouple may depend upon its characteristics and other factors such as its distance from the strip **10** but, despite such a correction, the reading of such thermocouple is close enough to enable it to be a highly satisfactory control instrument in this art.

The following Table I sets forth an operation comprising one practice of the new system of this invention for a variety of weights of a strip **10** of ferrous material. In Table I the indicated furnace gas atmosphere in pass chambers **16** and **18** was maintained in the neighborhood from about 1750° F. to about 1800° F., while the indicated furnace gas or zone temperature in pass chamber **20** was maintained in the neighborhood between from about 1400° F. to about 1600° F., the lower temperatures in the range being used with ferrous strip **10** of greater mass per unit length. Almost all of the runs shown in Table I took place with the admission of air through pipe pair **78** only although a few were made with the pair of admission pipes **78** shut off and with air admission through admission pipes **79**. Throughout the runs, the valves **80** for pipes **77** were tight-shut. In general, there is no material difference in the operation of the new system of this invention as between admission through pair **78** and admission through pair **79** except that for ferrous strip of somewhat more extensive surface area, admission through pair **78** makes a slightly longer reaction period of time available. Throughout the runs also the volume of air admitted through the aforesaid admission pipes was of the order of from 4 to 5 cubic feet per minute at a pressure generally slightly above the pressure of the furnace gas atmosphere and at a temperature in the neighborhood of room temperature. The air so introduced as the oxygen-containing gas was relatively dry, it having originally been compressed, but it may be saturated with water vapor without detriment to the operation of the invention. Any source of oxygen-containing gas such as air or other gas which contains uncombined oxygen and is not deleterious to the strip **10** or the coating to be formed thereon may be used whether or not initially compressed provided it has sufficient pressure to flow through the selected pair of admission pipes.

All of the column headings in Table I pertain to the strip. The steel temperature readings in Table I are those from the indicated thermocouples and require correction of the order shown in Figure 6 to obtain the estimated actual temperature of the ferrous strip.

*Table I*

| Width of Strip in Inches | Weight in Pounds per Lineal Foot | Speed in Feet Per Minute | Tons per Hour Through Furnace 12 | Indicated Temperature of Steel Strip | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | 56* | 57* | 58* | 59* | 60* | 61* |
| 24½ | 1.23 | 200 | 7.4 | 1,230/1,250 | 980/1,020 | 1,280/1,310 | 800/840 | 640/660 | 760/780 |
| 24½ | 1.31 | 180/190 | 7.1/7.5 | 1,220/1,240 | 1,000/1,020 | 1,280/1,320 | 820/850 | 640/660 | 760/780 |
| 28½ | 1.45 | 170/180 | 7.4/7.8 | 1,150/1,160 | 1,040/1,060 | 1,260/1,280 | 840/860 | 640/660 | 770/780 |
| 33 | 1.38 | 190 | 7.8 | 1,150/1,170 | 1,100/1,120 | 1,300/1,310 | 860/890 | 640/660 | 770/790 |
| 28½ | 1.53 | 160 | 7.3 | 1,180/1,200 | 1,040/1,060 | 1,260/1,280 | 830/850 | 620/640 | 760/780 |
| 26 | 2.24 | 90/100 | 6.1/6.7 | 1,240/1,260 | 1,140/1,160 | 1,330/1,350 | 850/870 | 630/650 | 770/790 |
| 30½ | 1.96 | 110 | 6.5 | 1,210/1,230 | 1,140/1,160 | 1,320/1,340 | 840/860 | 580/600 | 720/740 |
| 21½ | 1.10 | 200 | 6.6 | 1,260/1,280 | 1,000/1,020 | 1,300/1,320 | 780/800 | 620/640 | 760/780 |
| 21 | 1.08 | 200 | 6.5 | 1,260/1,280 | 1,000/1,020 | 1,310/1,330 | 780/800 | 620/640 | 760/780 |
| 24 | 1.24 | 200 | 7.4 | 1,220/1,240 | 980/1,000 | 1,280/1,320 | 820/840 | 660/680 | 780/800 |
| 23 | 1.23 | 180 | 6.7 | 1,240/1,260 | 980/1,000 | 1,300/1,320 | 820/840 | 640/660 | 760/780 |
| 23½ | 1.39 | 170 | 7.1 | 1,240/1,260 | 980/1,000 | 1,300/1,320 | 820/840 | 640/660 | 760/780 |
| 20 | 1.07 | 200 | 6.4 | 1,260/1,280 | 1,000/1,020 | 1,300/1,320 | 780/800 | 620/640 | 760/780 |
| 24½ | 1.01 | 210/220 | 6.35/6.65 | 1,220/1,240 | 1,020/1,040 | 1,280/1,300 | 800/820 | 640/660 | 800/820 |
| 24½ | 1.02 | 210 | 6.4 | 1,220/1,240 | 1,060/1,080 | 1,280/1,300 | 810/830 | 640/660 | 760/780 |
| 25½ | 1.65 | 135 | 6.8 | 1,250/1,270 | 1,230/1,250 | 1,330/1,350 | 900/920 | 540/560 | 750/770 |
| 20 | 1.02 | 215 | 6.6 | 1,270/1,280 | 1,030/1,050 | 1,230/1,240 | 720/740 | 600/610 | 750/770 |
| 23 | 1.17 | 200 | 7.0 | 1,250/1,270 | 1,010/1,040 | 1,210/1,240 | 740/770 | 610/630 | 750/770 |
| 25½ | 1.34 | 190 | 7.6 | 1,220/1,240 | 1,100/1,120 | 1,250/1,270 | 820/830 | 660/670 | 790/810 |
| 26½ | 1.40 | 180 | 7.6 | 1,230/1,260 | 1,120/1,150 | 1,270/1,290 | 850/870 | 680/690 | 780/800 |
| 26½ | 1.70 | 120 | 6.1 | 1,270/1,300 | 1,230/1,250 | 1,350/1,370 | 900/930 | 530/560 | 650/660 |
| 29 | 1.54 | 145 | 6.7 | 1,220/1,240 | 1,210/1,220 | 1,350/1,360 | 950 | 550/570 | 740/760 |
| 32½ | 1.73 | 145 | 7.5 | 1,200/1,220 | 1,180/1,200 | 1,340/1,350 | 960/970 | 670/680 | 760/780 |

*No. of thermocouple from which reading was taken.

In each of the treatments indicated in the foregoing Table I, a clear deep blue color oxide (which at least principally appears to be $Fe_3O_4$) was obtained which was relatively uniform in weight and in color and of an excellent adhering quality in respect of its bond with the base ferrous metal of strip **10**. Samples taken through a valve communicating with a port **82** indicate that no free oxygen remained by the time strip **10** reached the top of pass chamber **24**. Before the strip **10** passed through discharge roll seals **32**, the cooling thereof had reduced the temperature of the steel on an estimated actual basis to between from about 250° F. and about 350° F. Thus, no air or other oxygen-containing gas other than the measured amount admitted through the admission pipes was afforded access to strip **10** until its



formation of an undesired light blue oxide on the strip or on any oxide already formed thereon seems to begin to take place. Thus, in the tests shown in the following Table II, satisfactory clear deep blue oxide was obtained in the operation of the apparatus shown in Figure 1 with air introductions ranging between from about 2 cubic feet per minute and about 4 to 5 cubic feet per minute, such quantities being total volume rates introduced through both sides of the pair of admission pipes used. Above that quantity of air, the results were poorer in color and in quality of the aggregate oxides. Thus, in Table II the coating produced at air rates of 6 cubic feet per minute tended to produce cloudy oxide coatings and at the still higher air admission rate the unwanted light blue oxide formation appeared to predominate.

*Table II*

| Air Introduced in Cubic Feet/Minute | Air Introduced Through Pipes No.— | Estimated Actual Ferrous Strip Temperature in Degrees Fahrenheit [1] | Speed of Strip in Lineal Feet per Minute | Average Oxide Coating Weight in Grams per Square Foot | Furnace Gas Atmosphere Composition in Percent by Volume [2] | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $CO_2$ | | | $O_2$ | | | $H_2$ | | | CO | | | $H_2O$ | | |
| | | | | | *a* | *b* | *c* | *a* | *b* | *c* | *a* | *b* | *c* | *a* | *b* | *c* | *a* | *b* | *c* |
| 2 | 78 | 855 | 175 | 0.28 | 11.8 | 11.2 | 11.8 | 0.0 | 0.4 | 0.2 | 0.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.113 | 0.337 | 0.322 |
| 2 | 78 | 795 | 175 | 0.145 | 10.8 | 10.6 | 10.6 | 0.0 | 0.0 | 0.2 | 1.2 | 0.4 | 0.6 | 1.2 | 0.0 | 0.2 | 0.038 | 0.97 | 1.04 |
| 4 | 78 | 925 | 175 | 0.48 | 11.4 | 10.6 | 10.8 | 0.0 | 0.2 | 0.4 | 0.0 | 0.2 | 0.4 | 0.0 | 0.2 | 0.0 | 0.491 | 0.578 | 0.553 |
| 4 | 78 | 905 | 175 | 0.39 | ----- | 10.8 | 11.0 | ----- | 0.0 | 0.2 | ----- | 0.0 | 0.2 | ----- | 0.0 | 0.0 | ----- | 0.680 | 0.653 |
| 4 | 78 | 975 | 205 | 1.23 | 10.8 | 11.0 | 10.6 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.578 | 1.69 | 1.88 |
| 4 | 78 | 935 | 175 | 0.97 | ----- | 10.2 | 10.6 | ----- | 0.2 | 0.2 | ----- | 0.4 | 0.2 | ----- | 0.0 | 0.0 | ----- | 0.827 | 2.47 |
| 6 [3] | 78 | 935 | 175 | 0.593 | ----- | 10.4 | 10.8 | ----- | 0.6 | 0.4 | ----- | 0.4 | 0.4 | ----- | 0.0 | 0.0 | ----- | 0.337 | 0.434 |
| 8 [3] | 78 | 865 | 175 | 0.676 | ----- | 10.0 | 10.2 | ----- | 0.6 | 0.6 | ----- | 0.2 | 0.2 | ----- | 0.6 | 0.8 | ----- | 1.08 | 1.12 |
| 2 | 79 | 845 | 175 | 0.311 | 11.4 | 11.0 | 11.0 | 0.0 | 0.2 | 0.6 | 0.0 | 0.2 | 0.6 | 0.0 | 0.0 | 0.0 | 0.491 | 0.383 | 0.352 |
| 4 | 79 | 905 | 175 | 0.444 | ----- | 10.4 | 11.2 | ----- | 0.6 | 0.4 | ----- | 0.2 | 0.0 | ----- | 0.0 | 0.0 | ----- | 0.553 | 0.472 |
| 6 [3] | 79 | 920 | 175 | 0.608 | 10.8 | 10.4 | 12.0 | 0.0 | 0.6 | 0.2 | 1.2 | 0.2 | 0.0 | 1.2 | 0.2 | 0.0 | 0.0685 | 0.453 | 0.578 |
| 8 [3] | 79 | 955 | 175 | 0.706 | 10.8 | 10.0 | 11.8 | 0.0 | 0.8 | 0.0 | 1.2 | 0.6 | 0.0 | 1.2 | 0.2 | 0.0 | 0.0685 | 0.553 | 0.532 |

[1] Based on readings of thermocouple No. 59.
[2] Balance of composition substantially all nitrogen.
[3] Coating unsatisfactory.
*a*. Analysis of atmosphere entering Furnace 12.
*b*. Analysis of atmosphere near thermocouple No. 59.
*c*. Analysis of atmosphere near port 82.

temperature reached the aforesaid range between from about 250° F. to about 350° F. Further, it appeared that the desirable deep blue color oxide was obtained by the introduction of the measured volume of oxygen-containing gas through admission pipes **78** or **79**, as the case might be, when the temperature of the strip **10** on an estimated actual basis was in the neighborhood of a temperature in the range between from about 750° F. to about 1050° F. It appears that the range between from about 800° F. to about 1000° F. is a preferred temperature range for obtaining such a desirable color and kind of oxide.

In the following Table II, a number of tests appear setting forth results obtained in one practice of the new system of this invention when introducing air at different rates to the respective pair **78** and **79** of admission pipes used and showing the furnace gas atmosphere as well as the moisture content thereof. In general, the furnace gas atmosphere initially supplied by machine **42** to the interior spaces of the apparatus shown in Figure 1 is relatively dry. Thus, the furnace gas atmosphere or the components thereof may be passed through a drying tower before introduction into the interior spaces of the apparatus shown in Figure 1 to reduce the dew point of the atmosphere to a maximum of about 31° F. in the particular tests listed. Otherwise, dissociation of the water vapor may take place at temperatures beginning above about 1000° F. and thereby make oxygen available for reaction with strip **10** particularly at such temperatures to produce oxide coating thereon which may not have the desired properties and which will adversely affect the controllability of the new system of this invention. It appears that if there is a carryover of reactive oxygen into a zone where the actual steel temperature falls below about 750° F., a clouding of the strip or the

Thus, it appears that excessive oxygen introduced through the admission pairs **78** or **79** produces in part at least a light blue oxide (which may have the composition $Fe_2O_3$) which is not as commercially desirable as the deep blue oxide produced when the strip is between about 750° F. and about 1050° F. So long as the strip temperature remains in the range from about 750° F. to about 1050° F. in the presence of uncombined oxygen, substantially all of the oxide formed seems to have the desirable deep blue oxide character and properties. Reducing the speed of strip **10** in furnace **12** with the same volume of oxygen-containing gas admitted thereto seems to have the same effect as increasing the flow of oxygen-containing gas without any change in the speed of the strip.

The furnace gas composition used for the runs shown in Table I was substantially the composition shown in Table II. In general, the individual or combined percentages by volume of hydrogen and/or carbon monoxide are maintained below the lower explosive limit as a maximum. For a furnace having the general characteristics of the furnace shown in Figure 1, and with a pass chamber corresponding to pass chamber **24** of about 24 feet in height with the other parts thereof in proportion, approximately 3000 to 3500 cubic feet of furnace gas atmosphere would be introduced per hour into the interior spaces of the apparatus shown in Figure 1 through pipe **44**. And for such apparatus, satisfactory results are obtainable for strip speeds of between from about 80 and 225 linear feet per minute, the slower speeds being used for the heavier gauge strips with the greater masses to be heated in furnace **12**. And for operations of such order in the practice of this new system, the volumes of air introduced as the oxygen-containing gas either through admission pipes **78** or admission pipes **79** will generally

vary between about 120 cubic feet per hour and about 480 to 600 cubic feet per hour, such quantity of air being generally introduced in direct proportion to the linear speed of the strip or to the weight of oxide coating desired or to a combination of both. As described above, the linear speed of strip **10** in passing through furnace **12** will be dependent upon the annealing cycle which is selected to obtain the particular mechanical and metallurgical properties desired. In general, the heavier gauge strips move more slowly through the furnace because of their greater mass.

On the other hand, admission of too little of an oxygen-containing gas into the interior spaces of furnace **12** in either the fourth or fifth pass chambers may produce a deep blue oxide of very light weight which may be insufficient to fully protect the surface of the metal. In general, the control elements described herein for one practice of the new system of this invention will enable ferrous strip to be continuously annealed and blued with an adherent and clear deep blue oxide which is uniform in color lengthwise and transversely of the strip, uniform on both sides thereof, and of a weight desired. In general, the new system will be operated to produce a deep blue oxide coating weight between about 0.15 and about 0.85 grams per square foot of surface area on the ferrous strip **10**.

In Figure 5 there is shown a diagram in which air flow is plotted in cubic feet per minute as an abscissa against change in the weight of oxide coating in grams per square foot of strip surface in a test with the estimated actual temperature of the strip in the range between about 855° F. and 955° F. adjacent the admission pipes used. The strip speed in the Figure 5 operation was 175 feet per minute and the low metalloid strip used was 21 inches wide and .0148 inches thick. The plotting points denoting admission of said air flow through admission pipes 78 are marked *78a* and the plotting points denoting admission through admission pipes 79 are marked *79a*. Thus, it appears that the functional relation between oxide weight and volume of oxygen-containing gas admitted is substantially a parabolic one permitting relative flexibility in obtaining the particular oxide coating weight desired by the practice of this invention.

It should be noted that the coatings produced in the particular tests shown in Figure 5 were generally unsatisfactory above a total metered air admission of about 5 cubic feet per minute. However, such heavier coatings can be made in the desired deep blue oxide by increasing the air flow as shown in Figure 5 and correspondingly increasing the time at which the strip remains at a temperature in the range between about 750° F. and about 1050° F. In general also, the rate of reaction in the formation of oxide coatings will increase, with a corresponding decrease in the time required, to the extent that the temperature in the aforesaid range is in the higher parts of the range.

In another diagram, that of Figure 6, temperature has been plotted as an ordinate against elapsed time in seconds from the entry roll seals **13** for a low metalloid ferrous strip 21 inches wide and .0148 inch thick moving at a speed of 175 linear feet per minute. The dash line labeled "Estimated Actual Steel Temperature" shows as closely as may be estimated the actual steel temperature when correcting the indicated steel temperature thermocouple readings. The plotted points for the respective zone temperature settings on the zone thermocouples and the indicated steel temperatures of the ferrous strip thermocouples are correspondingly numbered to the numbers of the respective thermocouples as shown in Figure 1 with the addition of an "*a*" thereto.

Also by means of the new bluing system of this invention, a relatively shiny black oxide of attractive color and relatively uniform weight may be produced on a ferrous strip **10** by the introduction of an oxygen-containing gas through admission pipes **77**. In that operation, the valves **80** leading to admission pipes **78** and **79** would be closed. In general, the same furnace gas atmosphere, zone and strip temperature conditions and oxygen-containing gas admission conditions would obtain as those described above in connection with the production of the deep blue color oxide coating. However, it will be noticed that admission pipe pair **77** is located in a hotter portion of furnace **12** and that the strip temperature adjacent the admission pipes **77** is in the neighborhood of about 1100° F. or above. The oxidation reaction apparently proceeds to completion before strip **10** leaves pass chamber **20**. Indeed, it may be considered a general rule that whether producing the relatively shiny black oxide or the deep blue oxide, all uncombined oxygen introduced adjacent the strip should react with it before the temperature of the strip moves out of the range within which the black oxide or the deep blue oxide is respectively formed, as the case may be.

It is believed that the shiny black oxide may in principal part at least be FeO. The shiny black oxide so produced is somewhat less desirable from the standpoint of its adhesion to the base metal of a strip **10**. Hence, it would be used for relatively flat fabrications or in the manufacture, for example, of formed articles such as stovepipe having a relatively large and regular radius of curvature. The shiny black oxide so produced is clear and has considerable gloss.

In the practice of the new system of this invention in many of its various aspects, as the strip **10** emerges from the last of the chutes **31** or from chute **35**, it may be readily visually inspected. If there should be a variation, for example, in the uniformity of the color on the respective sides of the strip, then and in that event additional oxygen-containing gas may be supplied through the one of the admission pipes being used which is on the side of the strip which is somewhat lighter in color by adjustment of the needle valve **75** directly connected to that particular admission pipe of the admitting pair. For lightening the color of one side, a contrary adjustment might be made. In all cases, sufficient oxygen will be supplied to provide the desired weight of oxide coating.

The ferrous strip treated in accordance with this invention will generally be a low metalloid steel. However, the composition of the ferrous strip may vary considerably and embrace ferrous strip having compositions placing them in the class, for example, of silicon steels and may even be applied in some cases, to Bessemer steel strip. While the furnace gas atmosphere used in the illustrated practice of the invention had the composition shown, other non-scaling and non-explosive atmospheres which are not materially reducing relative to oxide formed may also be employed. For most purposes, however, admission of air or other oxygen-containing gases without deleterious components therein will be supplied through but one of the pairs of admission pipes, the other remaining pairs in each of the admission pipes being individually adjustable as may be required. In some cases, as where a still heavier deep blue oxide coating may be wanted, a reheating section utilizing conventional heating tubes between the baffle **55** and the lower end of pass chamber **26**, for example, may be provided and used, in conjunction with the operation, for example, of either pair **78** or of pair **79**, to boost the actual temperature of the strip to a temperature at least as high as 750° F. but not above about 1050° F. actual strip temperature with the admission of a small amount of air or other oxygen-containing gas through similar admission pipes **55'** shown in dotted outline and operated in the same manner as any of the other pairs of admission pipes.

Similarly, if the reheat section as aforesaid is used to boost the strip temperature to a temperature above about 1100° F. and a small amount of air or other oxygen-containing gas is admitted through admission pipes **55'**, a further uniform weight of a relatively shiny black oxide

may thereby be added to that weight of black oxide coating previously formed on the strip by the use of admission pipe pair 77 as described above. On the other hand, admission pipes 55' may be used exclusively for the entire bluing operation in some cases to produce the character and quality of oxide coating desired but of a lighter weight than obtainable by the combined coating operation. In other respects also the apparatus of Figures 1 and 2 may be greatly varied without precluding the use thereof in the practice of this invention.

While certain methods of practicing the new system of this invention have been illustrated and described, it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously practiced within the scope of the following claims.

We claim:

1. A bluing method for ferrous strip, comprising in combination, continuously heating said strip in strand form to metal treating temperature, continuously supplying a controlled atmosphere to surround said strip during said heating, continuously reducing the temperature of said strip to a temperature in the range between about 750° F. and about 1050° F., continuously supplying a substantially non-oxidizing and non-reducing atmosphere surrounding said strip during said temperature reduction, and continuously admitting a predetermined regulated quantity of uncombined oxygen into said last-mentioned atmosphere adjacent said strip while at a temperature in said temperature range, said quantity being sufficient to produce a substantially uniform coating weight on the surface of said strip, and substantially entirely reacting said oxygen with said strip.

2. A bluing method for ferrous strip, comprising in combination, continuously heating said strip in strand form to annealing temperature, continuously supplying a controlled atmosphere to surround said strip during said heating, continuously cooling said strip to a temperature in the neighborhood of between from about 750° F. and about 1050° F., providing a non-oxidizing and non-reducing atmosphere surrounding said strip during said cooling, and introducing free oxygen-containing gas into said non-oxidizing and non-reducing atmosphere adjacent said strip while at a temperature in the neighborhood of between from about 750° F. and about 1050° F. in a predetermined regulated quantity sufficient to react with said strip while in said non-oxidizing and non-reducing atmosphere to produce a deep blue oxide coating of relatively uniform weight on the surface of said strip, and substantially entirely reacting said oxygen containing gas with said strip.

3. A bluing method for ferrous strip, comprising in combination, continuously heating said strip in strand form to a metal treating temperature, providing a non-scaling atmosphere surrounding said strip during said heating, continuously cooling said strip to a temperature in the range between from 750° F. to about 1050° F., providing a substantially non-oxidizing and non-reducing atmosphere surrounding said strip during said cooling, moving said strip during said heating and cooling at a speed in generally inverse relation to the mass of said strip per unit length thereof, introducing uncombined oxygen into said last-mentioned atmosphere and adjacent said strip at a regulated rate in the range between about 0.4 and about 1 cubic foot per minute while said strip is at a temperature between about 750° F. and about 1050° F., continuing the movement of said strip in said non-oxidizing and non-reducing atmosphere while substantially all of said oxygen reacts with said strip to form a substantially uniform weight of deep blue oxide coating thereon, and cooling said coated strip below any material oxidizing temperature thereof in an atmosphere substantially inert relative to said coating.

4. A bluing method for ferrous strip, comprising in combination, continuously moving said strip through a strand furnace at a speed between about 90 feet per minute and about 220 feet per minute in generally inverse relation to the mass of said strip per unit length thereof, continuously heating said strip in said furnace to an annealing temperature, surrounding said strip within said furnace during said heating with a non-scaling atmosphere, continuously cooling said strip in said furnace to a temperature between about 750° F. and about 1050° F., surrounding said strip during said cooling with a substantially non-oxidizing and non-reducing atmosphere, introducing air into said last-mentioned atmosphere adjacent said strip at a regulated rate between about 2 and about 5 cubic feet per minute while said strip is at a temperature between about 750° F. and about 1050° F., and continuing the movement of said strip in said non-oxidizing and non-reducing atmosphere while substantially all of the oxygen in said air reacts with said strip to produce a substantially uniform coating weight thereon.

5. A bluing method for ferrous strip, comprising continuously heating said strip in strand form to an annealing temperature, continuously supplying a controlled atmosphere to surround said strip during said heating, continuously reducing the temperature of said strip to a temperature in the range between about 750° F. and about 1050° F., continuously supplying a substantially non-oxidizing and non-reducing atmosphere surrounding said strip during said temperature reduction, continuously supplying a free oxygen-containing gas to said last-mentioned atmosphere adjacent said strip while at a temperature in said temperature range in a predetermined measured quantity sufficient to substantially entirely react with said strip while in said temperature range, continuously cooling said strip to a temperature below said temperature range, continuously reheating said strip to a temperature in said temperature range following said cooling, and continuously supplying additional free oxygen-containing gas adjacent said strip while in said temperature range due to such reheating in a quantity sufficient to substantially entirely react with said strip, said reactions producing a substantially uniform coating weight on the surface of said strip by substantially complete reaction of said oxygen containing gas with said strip.

6. A bluing method for ferrous strip, comprising in combination, continuously maintaining the temperature of successive portions of said strip while moving in strand form within a temperature range having a lower limit of about 750° F., continuously supplying a substantially non-oxidizing and non-reducing atmosphere to surround said strip, and continuously supplying a free oxygen-containing gas into said atmosphere and adjacent said strip while at a temperature in said temperature range in a predetermined measured quantity wherein the uncombined oxygen in said gas substantially entirely reacts with said strip while in said temperature range and in said atmosphere to produce a substantially uniform coating weight on the surface of said strip.

7. A bluing method for ferrous strip, comprising in combination, continuously heating said strip in strand form to an annealing temperature, providing a substantially non-oxidizing and non-reducing atmosphere surrounding said strip during said heating, introducing free oxygen-containing gas into said atmosphere adjacent said strip while at an annealing temperature at least above about 1100° F. in a predetermined measured quantity sufficient to react substantially entirely with said strip while in said non-oxidizing and non-reducing atmosphere to produce a black oxide coating of substantially uniform weight on the surface of said strip, substantially entirely reacting said oxygen with said strip and cooling said coated strip below any material oxidizing temperature thereof in an atmosphere relatively inert to said coating.

8. A bluing method for ferrous strip, comprising in combination, continuously heating said strip in strand form to an annealing temperature, continuously reducing

the temperature of said strip to a temperature in the range above about 1100° F., continuously supplying a substantially non-oxidizing and non-reducing atmosphere surrounding said strip during said heating and said temperature reduction, continuously supplying a free oxygen-containing gas into said atmosphere and adjacent said strip while at a temperature in said temperature range in a predetermined regulated quantity sufficient to substantially entirely react with said strip while in said temperature range, continuously cooling said strip to a temperature below said temperature range, continuously re-heating said strip to a temperature in said temperature range following said cooling, and continuously supplying additional free oxygen-containing gas adjacent said strip while in said temperature range due to such reheating in a quantity sufficient to substantially entirely react with said strip, said reactions producing a substantially uniform coating weight on the surface of said strip by substantially complete reaction of the oxygen with the strip.

9. In a bluing method for ferrous strips, the steps comprising, in combination, continuously passing said strip in strand form through a strand furnace having a plurality of zones, heating said strip during such passage to a heat-treating temperature in one zone, maintaining another zone through which said strip passes at a temperature in the range between about 1050° F. and about 750° F., supplying a substantially non-oxidizing and non-reducing atmosphere to said furnace at least in said last mentioned zone, and introducing a predetermined measured amount of a free oxygen-containing gas into said last-mentioned zone to substantially entirely react with said strip while in said temperature range, and in said last-mentioned zone to produce a substantially uniform coating weight on the surface of said strip and correlating said measured amount with said strip speed, surface and temperature to provide a deep blue oxide surface of desired weight on said strip prior to cooling said strip substantially below about 750° F. in a controlled protective atmosphere.

10. In a bluing method for ferrous strips, the steps comprising, in combination, continuously passing said strip in strand form through a strand furnace having a plurality of zones into cooling chutes, heating said strip during such passage to a heat-treating temperature in one zone, maintaining another zone through which said strip passes at a temperature in the range above about 1050° F., supplying a substantially non-oxidizing and non-reducing atmosphere to said furnace at least in said last-mentioned zone, and introducing a predetermined measured amount of a free oxygen-containing gas into said last-mentioned zone to substantially entirely react with said strip while in said temperature range, and in said last-mentioned zone to produce a substantially uniform coating weight on the surface of said strip and correlating said measured amount with said strip speed, surface and temperature to provide a black oxide surface of desired weight on said strip prior to the entry of said strip into said cooling chutes.

11. A bluing method for ferrous strip, comprising in combination, continuously moving said strip in strand form, continuously supplying a substantially non-oxidizing and non-reducing atmosphere to surround said strip, and continuously admitting a predetermined regulated quantity of free oxygen into said atmosphere adjacent said strip at at least one location during its movement while said strip is at a temperature in the temperature range extending from about 750° F. to about 1050° F., said free oxygen being sufficient to produce a substantially uniform coating weight on the surface of said strip by substantially entirely reacting with said strip while said strip is in said temperature range.

12. In a bluing method for ferrous strip, the steps comprising in combination, continuously moving said strip in strand form through a furnace, continuously regulating the temperature of said strip in said furnace so that it is at least above about 750° F., continuously introducing a substantially non-oxidizing and non-reducing atmosphere into the interior of said furnace to surround said strip when it is at such a temperature, continuously introducing a predetermined regulated quantity of uncombined oxygen into the interior of said furnace in a uniform flow adjacent and substantially parallel to both sides of said strip while it is at such a temperature, to produce a substantially uniform coating weight on the surface of said strip by substantially complete reaction of said uncombined oxygen with said strip.

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